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Volume

1

Final report

OWMC

**Ontario
Waste Management
Corporation**

A provincial crown corporation.



**Gartner
Lee
Associates
Limited**

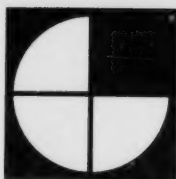
SITE ASSESSMENT
PHASE 4B:
GEOLOGY, HYDROGEOLOGY AND
GEOTECHNICS, BASELINE CONDITIONS
VOLUME 1

Prepared for
The Ontario Waste Management Corporation

Submitted By

Gartner Lee Limited

October, 1987



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October 30, 1987

GLL 87561

Mr. J.G. Micak
Manager, Environmental Projects
Ontario Waste Management Corporation
2 Bloor Street West, 11th Floor
Toronto, Ontario
M4W 3E2

Attention: Mr. D.F. Chollak,
Environmental Planner

Dear Sirs:

Re: Site Assessment Phase 4B: Geology,
Hydrogeology and Geotechnics
- Baseline Conditions

We are pleased to provide you with Volume 1 of the above noted three-volume report. This report is one of six Phase 4B companion reports describing baseline conditions, hydrogeologic inputs to landfill design, geotechnical inputs to facilities design, potential impacts of the landfill on ground water, potential impacts of the central operation area on ground water and ground water management strategies.

We thank you for this opportunity to be of service. Should you have any questions please do not hesitate to call.

Yours very truly,

GARTNER LEE LIMITED

E.G. Anderson
for E.G. Anderson, P.Eng.
Consulting Hydrogeologist
Project Director

GWR:emh

Glenn Reynolds
G.W. Reynolds, M.Sc.,
Senior Hydrogeologist,
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EXECUTIVE SUMMARY

PREFACE

This executive summary presents highlights of the three volume Gartner Lee Limited report titled Site Assessment - Phase 4B: Geology, Hydrogeology and Geotechnics, Baseline Conditions. Volume 1 documents the geologic, hydrogeologic and geotechnical setting of the Ontario Waste Management Corporation's Preferred Site as established from comprehensive field, laboratory and office studies. Volumes 2 and 3 contain the field and laboratory protocols, testing results and monitoring data summaries which support Volume 1.

This Report documents only a portion of the geoscience studies (which incorporates geology, hydrogeology, and geotechnics) carried out by Gartner Lee Limited as part of Phase 4B of the Ontario Waste Management Corporation's (OWMC) Facilities Development Process. Phase 4B involves detailed assessments of the Preferred Site and surrounding area based on several disciplines, including the geosciences. The Preferred Site and immediate vicinity are illustrated in Figure A.

1. Define the existing environmental conditions (baseline) of the preferred siting option,
2. Predict and assess potential risks and impacts that may be associated with the proposed facility design and operations,

Township of West Lincoln, Regional Municipality of Niagara. Local Detail.



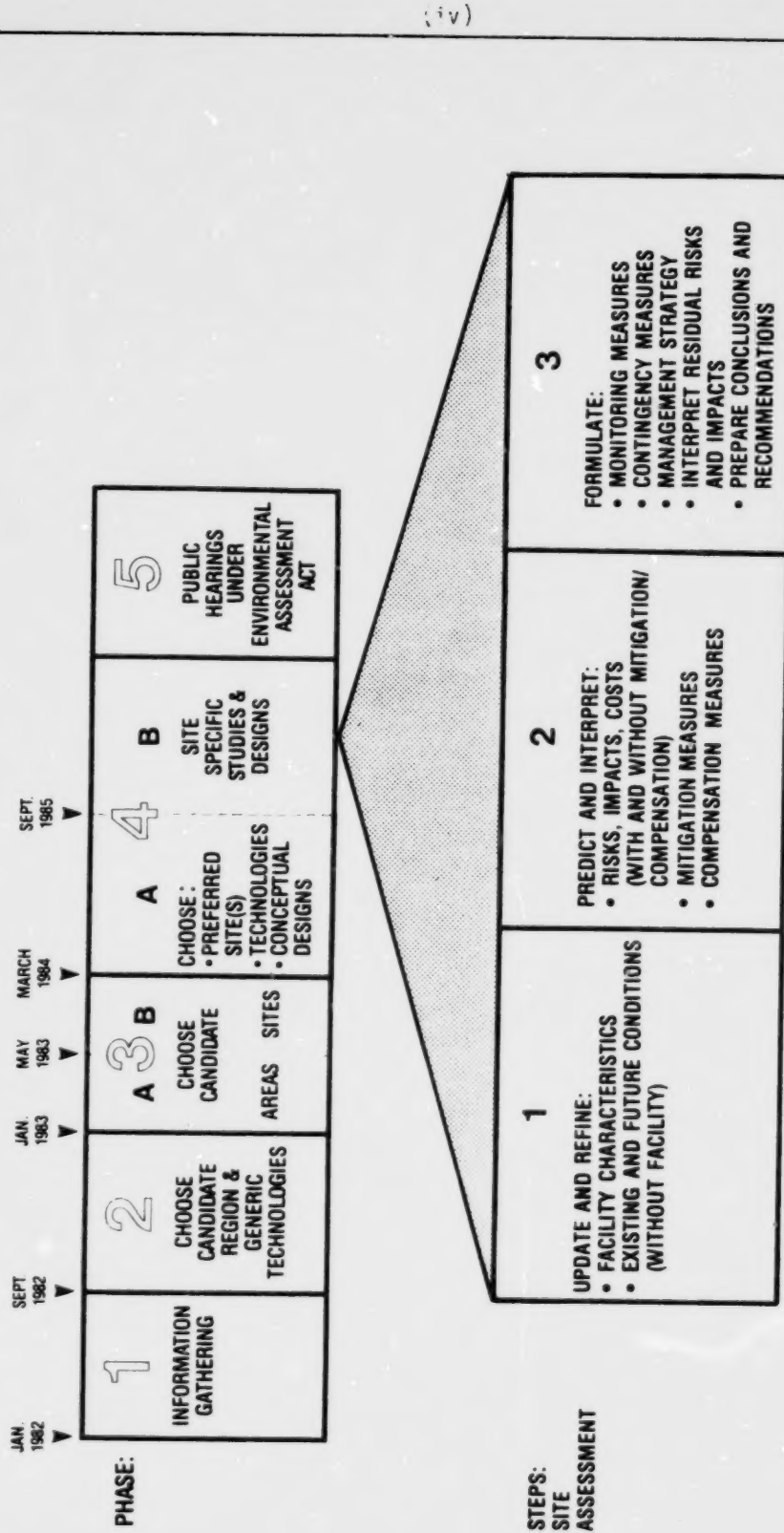
(iii)

3. Identify and develop appropriate mitigative measures to minimize the potential risks and impacts,
4. Predict and assess residual risks and impacts after mitigation,
5. Identify and develop monitoring and contingency programs that will be implemented to assess the effectiveness of the design and operations in minimizing risks and impacts, and
6. Prepare documentation to meet the requirements of Ontario's Environmental Assessment Act.

Figure B illustrates how Phase 4B relates to the other Phases of the OWMC Site Assessment and Facilities Development Process.

For the geosciences, Gartner Lee Limited's (GLL) Phase 4B studies have focused on:

1. Establishing baseline conditions for the Preferred Site (this report),
2. Providing required input to OWMC's engineering consultants for conceptual facilities design (GLL 1987a; 1987b),
3. Assessing potential ground water impacts from the Central Operating Area, (GLL 1987c),



OWMCG Ontario Waste Management Corporation

FACILITIES DEVELOPMENT PROCESS

DILLON

Figure B

(v)

4. Assessing, mitigating and comparing various engineered landfill design concepts as input to OWMC's selection of the shallow entombed landfill (GLL, 1987b),
5. Assessing potential ground water impacts from the shallow entombed landfill (GLL, 1987d), and
6. Developing an overall ground water management plan through monitoring, mitigation and contingency strategies (GLL, 1987e).

Figure C illustrates how this Report fits into GLL's Phase 4B studies.

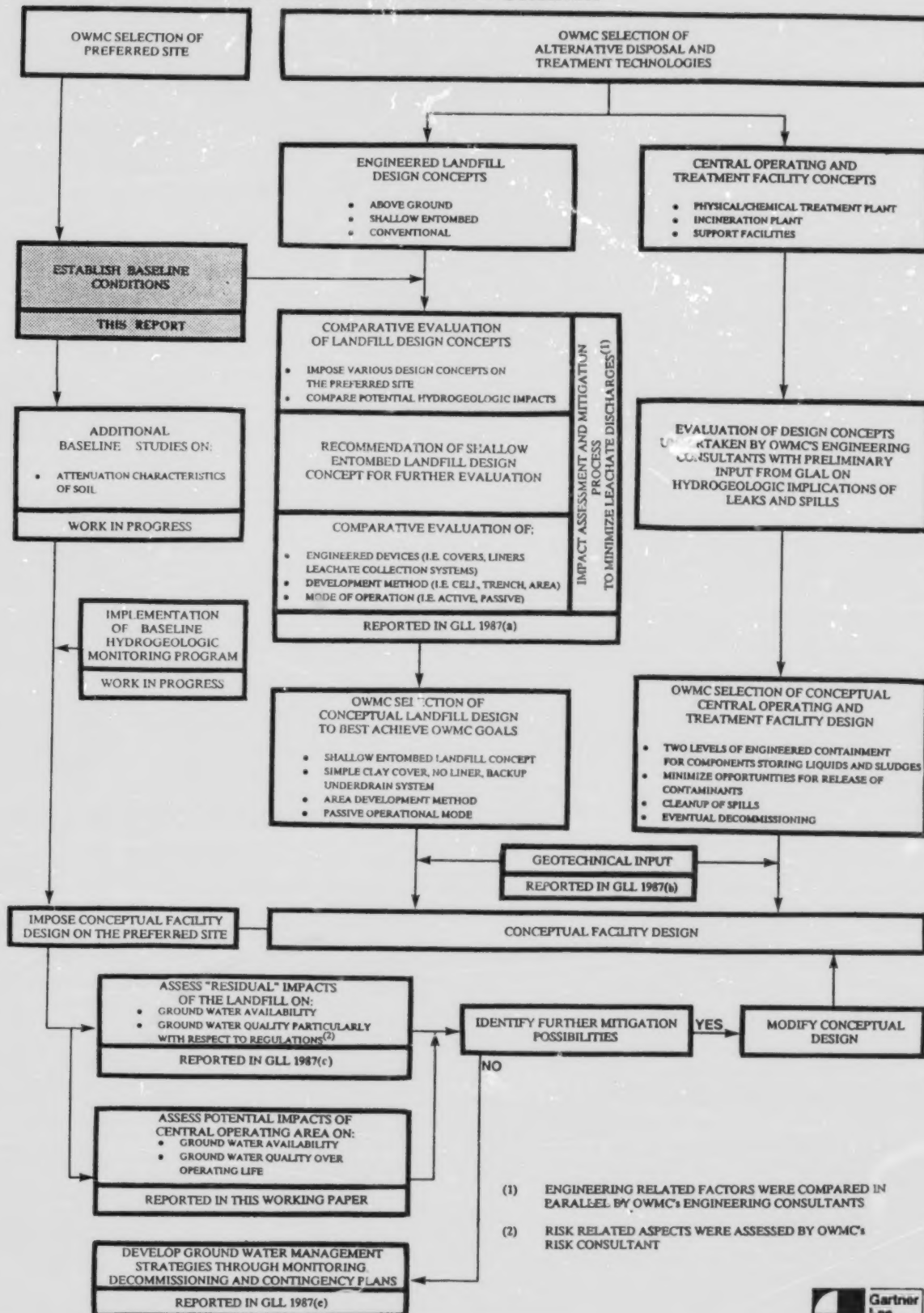
PURPOSE AND SCOPE

The purpose of this report is to document pre-facility conditions (baseline conditions) at OWMC's Preferred Site. This baseline information has been used as input to the other GLL Phase 4B studies listed above.

A secondary objective of the study program was the confirmation of the Phase 4A interpretation of the physical setting at the Preferred Site. OWMC's selection of the Preferred Site, was influenced by the presence of favourable hydro-geologic conditions as interpreted from preliminary drilling at the site (OWMC, 1985). The site selection process is documented in the series of Facilities Development Process reports prepared by OWMC (1982; 1983a; 1983b; 1984; 1985). The role of the geologic/hydrogeologic consultant in the site selection process is documented in a series of supporting reports prepared by Gartner Lee Associates Limited (GLAL 1982a; 1982b; 1983; 1984a; 1984b; 1985)¹.

1. Gartner Lee Associates Limited changed its name to Gartner Lee Limited in November, 1986.

FIGURE C
PHASE 4B: IMPACT ASSESSMENT APPROACH: Geoscience



SCOPE AND METHODS

The Phase 4B baseline geoscience study program combines investigations in geology, geophysics, physical hydrogeology, geochemistry, ground water use and geotechnics. The investigations for each discipline generally entailed:

- development of a detailed work plan and protocols for field studies;
- field studies which included both surface and sub-surface work such as drilling, testing, sampling, monitoring and interviewing of local residents, agency and university staff familiar with the study area;
- laboratory testing; and
- data compilation, analysis, interpretation and reporting.

The work plan is a guide to the various activities and tasks undertaken during the program (GLAL, 1986). The protocols consist of procedural directives to guide field staff. The protocols are presented in full in Appendix A and Appendix B of the report.

An overview of the field studies, laboratory tests and analytical techniques specific to each discipline is contained in Section 1.3 of this volume. Procedural details are contained in the section of the report pertaining to the particular discipline and in the supporting appendix (Volumes 2 and 3).

PREMISES AND POSTULATES

The identification of the appropriate scope of the study and the approach to data collection and interpretation was established by the GLL Study Team in consultation with OWMC personnel. Data collection and analysis procedures employed during Phase 4B were consistent with those in general practice for the various disciplines. Wherever possible, published standard methods were followed.

STATUS OF DATA

The information base collected during the Phase 4B geoscience program is considered to be acceptable for its intended purpose, namely the definition of pre-facility conditions (baseline conditions) at the Preferred Site. This information has been used by OWMC's engineering consultants in the conceptual design of the proposed OWMC facility and will provide the basis for GLL's assessment of potential impacts on ground water resources. The baseline information can also be used as the basis for comparison with future performance monitoring.

FINDINGS

GEOLOGY

The geology of the Preferred Site study area is described in Section 2.0 of this volume.

The topography is for the most part, flat with relief provided by small ridges and swales. The study area is underlain by four overburden geologic units of Quaternary age which from surface to depth (youngest to oldest) are:

- (1) Upper Glaciolacustrine Unit;
- (2) Halton Unit;
- (3) Lower Glaciolacustrine Unit; and
- (4) Lower Till

All four units were encountered in the deep boreholes completed in the study area. The Quaternary units are in turn underlain by dolostone bedrock of the Guelph and Lockport-Amabel formations.

The Upper Glaciolacustrine Unit extends from surface or near surface (locally underlies a thin deposit of sediment in swales) to a depth ranging between 5.1 and 8.2 m on site and slightly deeper, to 9.1 m, north of the site. Texturally, the unit lies between a clayey silt and a silty clay. This unit is commonly laminated with massive zones and contains occasional silt laminae to several millimetres in thickness.

The Upper Glaciolacustrine Unit is heavily weathered to a depth of about 1 m. Fractures are frequent to approximately 3 m, occasional to 5 or 6 m and rare or not observed below 6 m. Fractures were not observed below swales. Many of the fractures were infilled with grey, carbonate rich, clay textured material. Gypsum crystals were occasionally noted in fractures. For the most part, fractures were observed to be very tight (thin aperture width) or infilled beneath approximately 3 m.

The Halton Unit is comprised of a sequence of inter-bedded till (mainly waterlain) and glaciolacustrine sediments.

(x)

This unit ranges from 12.7 to 16.8 m in thickness on-site and 11.8 to 18.5 m off-site. In general, the till portions of the Halton Unit are massive to slightly laminated clayey silts with 10% or more rock clasts (>0.02 mm in diameter). The glaciolacustrine sediments are generally poorly to moderately well laminated clayey silts containing significantly fewer rock clasts (to 4%). The proportion of till within the Halton Unit averages about 35% but ranges from 90% or more in the north to 0% in the south.

The Lower Glaciolacustrine Unit is composed of approximately equal portions of silt and clay with minor amounts (to 5%) of disseminated sand particles. The unit is generally well laminated. This unit ranges in thickness from 7.8 m to 14.6 m.

The Lower Till which directly overlies the bedrock is composed of approximately equal portions of gravel, sand and silt with commonly 5 to 10% clay. The unit ranges from slightly less than 1 m in thickness at borehole location 84-2, the northeastern corner of the site, to a maximum of more than 5 m at borehole location 85-10, the southwestern corner of the site. South of the site, at borehole location 85-14 the unit is more than 10 m thick.

The Guelph Formation which was encountered in all boreholes penetrating to bedrock, is a finely crystalline, sugary-textured dolostone with occasional shale laminae and vugs. The upper metre or two of rock encountered in each borehole was fractured. Fractures decreased in frequency below this depth and generally occurred only along shale laminae. Many of the fractures and vugs contained gypsum.

The Lockport-Amabel Formation was encountered at depth in two deep boreholes completed at the northwest and southeast corners of the Preferred Site, respectively.

The contact between the Salina Formation and Guelph Formation occurs about 1 km south of the Preferred Site. The Salina Formation is comprised of dolostone, shale and evaporites.

The bedrock surface slopes gently towards the south from an elevation of approximately 155 m at the northeast corner to 146 m at the southeast corner. The geophysical profiling suggests that the relief on the bedrock surface is on the order of 2-3 metres.

On-site overburden thickness ranges from about 30 m in the north to 38 m at the southeast corner of the site. The overburden thickness decreases to approximately 27 m one km north of the site. Immediately south of the site, the overburden thickness increases to about 39 m.

In summary, the site is underlain by a 30 to 38 m thick layer of silt-clay which is continuous and exhibits lateral and vertical textural uniformity.

PHYSICAL HYDROGEOLOGY

The physical hydrogeologic properties of the major hydrostratigraphic units in the Preferred Site area are described in Section 3.0 of this volume. Also provided is a discussion of ground water flow in a regional and local context.

The following hydrostratigraphic units and subunits were derived from a review of the hydrogeologic properties of the geologic units.

GEOLOGIC UNIT	GROUP	HYDROSTRATIGRAPHY UNIT
UPPER GLACIOLACUSTRINE UNIT	Overburden Aquitard	WEATHERED SILT AND CLAY
HALTON UNIT		UNWEATHERED SILT AND CLAY
LOWER GLACIOLACUSTRINE UNIT		
LOWER TILL		LOWER TILL
GUELPH AND LOCKPORT-AMABEL BEDROCK FORMATIONS	Bedrock Aquifer	ZONE A ZONES B TO E

The physical hydrogeologic properties of the hydrostratigraphic units, as determined by field and laboratory testing, and theoretical analysis including mathematical modelling, are summarized in the accompanying table. The results of the hydrogeologic investigation compare favourably with published results conducted in the general vicinity of the Preferred Site. The ground water flow characteristics, including principal flow direction, hydraulic gradient, specific discharge and average linear velocity are also included in this table.

Ground water flow at the Preferred Site consists of both shallow (dynamic) and deep (steady state) flow components. During major precipitation events, the water table rises and the ridge and swale topography dominates shallow ground water flow. Infiltration along the ridges flows very rapidly, laterally through the weathered silt and clay towards discharge in adjacent swales. Between precipitation events, the water table exists at or below the base of the swales. The shallow flow component buffers transient recharge events; as a consequence, deep flow can essentially be considered as steady state. This results in extremely slow (3.8 mm/a) steady downward flow through the unweathered silt and clay towards the Bedrock Aquifer. By contrast, lateral flow in the Bedrock Aquifer is orders of magnitude faster. Flow in the Bedrock Aquifer is in a southerly direction under low hydraulic gradients. The bulk of ground water flow occurs through the permeable zones in the bedrock, particularly Zone A (uppermost).

Regionally, the ground water flow direction in the Bedrock Aquifer is from a ground water divide, located approximately one to two km north of the site, southwards towards the Welland River. The regional gradients in the vicinity of the Welland River are low and poorly defined. Upward gradients likely exist beneath the Welland River, as can be inferred from the presence of flowing wells in the general area. Because of the sluggish lateral flow in the bedrock, the Welland River likely acts as the regional divide and discharge point for the bedrock aquifer, despite the river's location in fine grained sediments. However, flow further southward or flow deflected further eastward along the river is also possible.

SUMMARY OF THE HYDROGEOLOGY OF THE PREFERRED SITE

HYDROSTRATIGRAPHY		AVERAGE PHYSICAL PROPERTIES			AVERAGE GROUND WATER FLOW PROPERTIES			
GROUP	UNIT	THICKNESS (m)	HYDRAULIC CONDUCTIVITY (m/s)	POROSITY	PRINCIPAL FLOW DIRECTION	HYDRAULIC GRADIENT	SPECIFIC DISCHARGE (m/a)	AVERAGE LINEAR VELOCITY (m/a)
AQUITARD	WEATHERED SILT AND CLAY	~ 5	2E-8 ⁽¹⁾	0.43 0.0001 ⁽²⁾	LATERAL TO SWALES	VARIABLE	--	--
	UNWEATHERED SILT AND CLAY	~ 28	2E-10	0.41	DOWNWARD	0.25	0.0016	0.0038
	LOWER TILL	~ 3	2E-8 ⁽¹⁾	0.16	DOWNWARD	0.25 ⁽³⁾	0.16 ⁽¹⁾	0.99 ⁽¹⁾
BEDROCK AQUIFER	ZONE A	6	2E-4	0.01 ⁽⁴⁾	LATERAL SOUTH	0.0002	1.3	130
	ZONE B	3	2E-7	NOT MEASURED	NOT MEASURED	NOT MEASURED	--	--
	ZONE C	9	>2E-5	0.05 ⁽⁴⁾	LATERAL SOUTH	0.0003	>0.19	>3.8
	ZONE D	9	<2E-9	NOT MEASURED	NOT MEASURED	NOT MEASURED	--	--
	ZONE E	3	2E-6	0.05 ⁽⁴⁾	LATERAL SOUTH	0.0005	0.032	0.63

(xiv)

- NOTES:
- (1) Highly variable, typical values shown.
 - (2) Estimated fracture porosity based on literature review.
 - (3) Assumed value.
 - (4) Estimated fracture porosity based on method of Snow (1968).

In summary, the hydrogeology of the Preferred Site was found to be highly uniform and predictable, as was anticipated in earlier hydrogeologic assessments of the site (GLAL, 1985).

GROUND WATER CHEMISTRY

Baseline ground water quality, established for both the Overburden Aquitard and Bedrock Aquifer, is described in Section 4.0 of this volume.

Ground water quality in the overburden evolves with depth from a zone of high total dissolved solids in about the upper 9 m (called shallow overburden ground waters) to ground waters below this depth which are much lower in total dissolved solids (called deep overburden ground waters). The main characteristics of these ground waters are as follows:

	Depth	Total Dissolved Solids	Main Constituents
shallow overburden ground waters	above about 9 m	≈9000 to 20000 mg/L	sulphate (≈5000 to 9500 mg/L) magnesium (≈1000 to 2500 mg/L)
deep overburden ground waters	below about 9 m	≈1000 mg/L	sulphate (≈400 to 800 mg/L) sodium (≈200 mg/L)

The shallow overburden ground water quality is the result of weathering in the upper few metres of the Overburden Aquitard. Due to differential weathering the quality is quite variable spatially and with depth.

Quality of the deep overburden ground water is relatively consistent across the site and with depth.

Bedrock ground water quality was determined in the upper 3 m of the rock. Most domestic bedrock wells in the area obtain their water supply from this zone. Bedrock ground water quality is very hard but generally of good quality. A few constituents, mainly aesthetic, exceed the Ontario Drinking Water Objectives. These are summarized below.

Parameter	Concentration Range in Bedrock	Ontario Drinking Water Objective	Exceeds Objective by
total dissolved solids	2360 to 2960 mg/L	500 mg/L	400 to 500%
sulphate	1370 to 1650 mg/L	500 mg/L	175 to 225%
fluoride*	2.14 to 2.73 mg/L	2.4 mg/L	Only 3 out of 8 values exceed. Maximum exceedance is 14%

* health related

Ground water samples were collected to analyse for environmental isotopes including tritium, oxygen-18, deuterium and carbon-14. The isotope results were used to assess the probable depth of active ground water flow in the near surface

of the overburden and to provide additional evidence that ground water flow and solute transport processes are very slow.

Tritium was detected in shallow ground waters down to a depth of between 3 and 5 m. No tritium was detected below this depth in the overburden or bedrock ground waters. Tritium is an indicator of waters recharged since the early 1950s. This implies that the zone of recent recharge and "active" ground water flow in the shallow subsurface does not extend below 5 m.

Oxygen-18 and deuterium isotope contents of the overburden ground waters decline regularly with depth from values typical of modern, temperate precipitation at the water table to values near those expected for colder, glacial waters. This indicates that solute transport downward through the unweathered silt and clay is very slow, since even after approximately 10,000 years of downward ground water flow (since the end of glaciation), ground waters deep in the overburden still retain part of their glacial character.

Oxygen-18 and deuterium contents of bedrock ground waters were more positive than at the base of the overlying overburden. This indicates that bedrock ground waters below the Preferred Site are not recharged solely by downward flow through the overburden, but also include a component of bedrock flow from upgradient areas.

GROUND WATER USE

Sources of water supplies for domestic livestock and general

agricultural purposes in the Preferred Site study area are described in Section 5.0. Most residences and farming operations rely on individual water supply systems which may use ground water, rain water, pond water, creek water, bottled or purchased water, or any combination of these, as a source of supply.

Water use information was obtained for a total of 115 separate parcels of land in the general vicinity of the Preferred Site. The study area includes the Preferred Site and an area extending about 2 km outwards from the Preferred Site to the east, north and west, and all land between the Preferred Site and the Welland River.

The total estimated water use for the study area is 411 cubic metres per day (m^3/d). Domestic use including drinking water and undifferentiated household water accounts for about 170 m^3/d (41%), livestock watering about 234 m^3/d (57%), agricultural spray water about 1 m^3/d (0.2%) and commercial and community use about 6 m^3/d (1.4%). Bedrock wells supply about 268 m^3/d or 65.0%, overburden wells 15 m^3/d (3.6%), cisterns 94 m^3/d (23.2%) and surface water 34 m^3/d (8.2%).

Water use for various sources of supply is not distributed uniformly across the study area. Less water is used in the south compared to the northern portion of the study area. This is attributed to the greater use of water in the north for livestock watering, washing etc.

Bedrock wells are the single most important source of water supply in the north, supplying an estimated 199 m³/d of water. Cisterns supply about 39 m³/d, followed by surface water (21 m³/d) and overburden wells (7 m³/d). In the south, water use requirements are satisfied principally by bedrock wells (70 m³/d) and cisterns (55 m³/d) followed by surface water (12 m³/d) and overburden wells (8 m³/d).

Greater usage is made of bedrock wells as a source of supply for both domestic and livestock watering purposes in the north (194 m³/d) versus the south (70 m³/d). In addition, greater usage is made of cisterns in the south (55 m³/d) than in the north (39 m³/d). This is in part attributed to water quality differences in the underlying bedrock. The northern portion of the study area is underlain by the Guelph Formation, while about 50% of the southern portion is underlain by the Salina Formation. The water quality of the Guelph Formation is relatively good while the water quality of the Salina Formation, is regionally poor with elevated concentrations of calcium, sodium, potassium, sulphate and chlorides.

GEOTECHNICS

The geotechnical program described in Section 6.0 of this volume, focuses on providing the necessary preliminary or background information for a conceptual design of the proposed landfill slopes and foundations for the various proposed structures. The discussion contained in this volume pertains to the classification and preliminary assessment of the engineering properties of the soils at the Preferred Site. A general discussion of slope, foundation and related construction considerations are contained in GLL 1987a.

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The four stratigraphic soil units described in the geology section (Section 2.0), have been further subdivided into eight subunits based on soil stratigraphy, engineering characteristics and shear strength parameters. Generalized soil properties and classifications were based on visual and tactile examination of the soil samples and laboratory test results. Due to the apparent sensitivity of the soil subunits, Standard Penetration Test results ("N" values) were used only to provide a qualitative guide to insitu conditions. The general soil classification of these subunits are summarized as follows:

SUMMARY GEOTECHNICAL CLASSIFICATION OF SOIL UNITS AT LF-9C

UNIT	SUBUNIT	APPROX. THICKNESS (m)	SOIL CHARACTERISTIC PROPERTIES
1 - Upper Glacio-lacustrine Unit	1A	3.3	clayey silt, very stiff, medium plasticity
	1B	1.4	silty clay, stiff to very stiff, high plasticity
	1C	2.2	clayey silt, very stiff, medium plasticity
2 - Halton Unit	2A	4.6	clayey silt, very stiff to stiff, low plasticity
	2B	10.3	clayey silt, stiff to very stiff, low to medium plasticity
3 - Lower Glacio-lacustrine Unit	3A	7.0	clay and silt, stiff, medium to high plasticity
	3B	3.9	silt and clay, stiff to firm, medium to high plasticity
4 - Lower Till	4	2.8	very dense to compact till

The general soil characteristics of any individual sub-units are very similar across the site. In addition, the soil units at the Preferred Site are interpreted to exhibit engineering characteristics somewhat similar to those encountered along the Welland Canal re-alignment. However, the units are thicker and demonstrate less stratigraphic complexity in the vicinity of the Preferred Site.

An overall geotechnical view of the site may be seen in section on Figure 6.1. Although the data points show considerable scatter, several important trends are apparent as follows:

1. The clayey soils seem to be only slightly overconsolidated at depth and become increasingly overconsolidated towards surface.
2. The overconsolidation trend is accompanied by a related trend of increasing strength towards surface.
3. Except for the effects of a near surface, higher plasticity layer (Unit 1B), there is a slight increase in water content and related decrease in unit weight with depth.
4. The clayey soils as a group display a fairly high sensitivity, S_t (by lab vane) and a low ratio of undrained strength to preconsolidated pressure (C_u/p^1c) which seems characteristic of clayey soils in this area.
5. The above trends are important in developing design philosophies for foundations and slopes at the site.

In summary, there do not appear to be any major geotechnical factors which would prevent the design and construction of engineered landfill excavations and building foundations proposed for the site. However, based on our understanding of the subsurface conditions it appears that all eight subunits will require further definitions during subsequent detailed geotechnical studies prior to the final design of the facility.

CONCLUSIONS

The Phase 4B geoscience program established pre-facility site conditions (baseline conditions) at OWMC's Preferred Site. This consisted of:

- the identification of the major geologic, geotechnical and hydrostratigraphic units at the Preferred Site;
- the determination of the general geotechnical and hydrogeologic properties of these units;
- the assessment of the direction and rate of ground water movement in the subsurface at the Preferred Site: and
- the establishment of overburden and bedrock ground water quality.

The collected baseline information is sufficiently comprehensive to be used as input in the prediction of potential impacts on local ground water resources from facility

construction and operation (GLL, 1987c and d). Impacts are expressed as changes in the ground water flow system and/or changes in ground water quality, with the baseline conditions providing the basis for comparison.

The preliminary geotechnical information collected during the Phase 4B geoscience program provides the necessary input to the conceptual design of the proposed landfill slopes and foundations for the various proposed structures (GLL, 1987b).

Baseline information presented in this report supports the Phase 4A interpretation of the physical setting at the Preferred Site (GLAL, 1985). Field and laboratory testing at the Preferred Site confirms that the thick layer of silt clay is continuous and exhibits lateral and vertical textural uniformity and that the hydraulic conductivity of the clay silt soils is low. Downward ground water flow, based on this testing, is expected to be very slow (3.8 mm/a or less). Results of isotope analysis of overburden waters further confirm the slow rate of flow.

RECOMMENDATIONS

Additional information should be collected to facilitate future assessment of potential impacts from OWMC's proposed facilities. This information will result in the better definition of local and regional ground water flow patterns, and will provide a more extensive pre-development water quality data base.

- (1) Studies including the construction of test pits to observe fracture frequency, aperture and interconnection, continuous water level monitoring in the weathered zone and additional slug testing of shallow monitors should be undertaken to better define both the physical properties of the weathered materials and shallow ground water flow through these materials.
- (2) Water wells in the general vicinity of the Preferred Site should be sampled to establish background water quality specific to the wells. Well water quality may not be similar to the water quality in on-site monitors. This is because localized sources of contamination such as septic tanks, manure storage areas etc. may affect shallow overburden wells and bedrock wells may be deeper than on-site monitors. In addition, water quality information for the Salina Formation is not available in the vicinity of the Preferred Site.
- (3) Upgradient and downgradient bedrock wells and monitors should be sampled for oxygen-18 and deuterium isotopes. This would enhance the definition of the regional hydrogeology. As well, the overburden and bedrock monitors should be resampled for radiocarbon age dating.
- (4) A baseline monitoring program should be developed to better define the magnitude of water level fluctuations and natural ground water quality changes with time. The program should include monitors and selected water wells. Monitors which will not be used should be properly sealed and abandoned.

(xxv)

- (5) Similar protocols to that which have already been developed should be followed for future investigations to ensure that any investigative borings do not breach the aquitard and are properly sealed and abandoned.

STUDY TEAM

The Phase 4B geoscience study program was completed under the overall direction of E.G. Anderson, Project Director and G.H. Funk, Project Manager. Gartner Lee Limited (GLL) staff responsible for the various study components, technical advisors and subcontractors are listed below:

Drilling Related Work

- Drilling Supervision - N.M. Woerns, GLL
S.C. Hollingshead, GLL
- Subcontractors
 - All-Terrain Drilling Limited
Waterloo, Ontario
 - W.A. McClenaghan Enterprises Inc.,
Brampton, Ontario
 - R. Griffin Construction Limited
Caistor Centre, Ontario
 - Culp Electric Limited,
Smithville, Ontario
 - Smith's Water Delivery,
Campden, Ontario
 - Farr Drainage Limited,
St. Catharines, Ontario
 - Matthews and Cameron Limited,
St. Catharines, Ontario
 - R. MacPherson
 - Y. Flameling

Laboratory Services

- Subcontractors
 - Golder Associates (Eastern
Canada) Limited,
Mississauga, Ontario

Laboratory Services (cont'd)

- Subcontractors
- Isotope Laboratory,
Department of Earth Sciences,
University of Waterloo,
Waterloo, Ontario
 - Isotrace Laboratories,
University of Toronto,
Toronto, Ontario
 - Rosentiel Isotope Laboratory,
University of Miami,
Florida
 - Agri-Food Laboratories,
Guelph, Ontario

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METRIC CONVERSIONS

Length

1 metre (m)	=	3.28 feet
1 kilometre (km)	=	0.62 miles
1 kilometre	=	1,000 metres
1 metre	=	1,000 millimetres (mm)

Area

1 square metre (m ²)	=	10.76 square feet
1 square kilometre (km ²)	=	0.39 square miles
1 hectare (ha)	=	2.47 acres
1 square kilometre (km ²)	=	100 hectares
1 hectare (ha)	=	10,000 square metres

Liquid Volume

1 litre (L)	=	0.22 imperial gallons
-------------	---	-----------------------

Flow

1 litre/second (L/s)	=	13.20 imperial gallons/minute
1 cubic metre/day (m ³ /d)	=	220 imperial gallons/day
1 cubic metre/day (m ³ /d)	=	1000 litres/day

Specific Capacity

1 litre/second/metre (L/s/m)	=	4.02 imperial gallons/ minute/foot
------------------------------	---	---------------------------------------

Transmissivity

1 square metre/day (m ² /d)	=	67.05 imperial gallons/ day/foot
--	---	-------------------------------------

Hydraulic Conductivity

1 metre/second (m/s)	=	176.6 imperial gallons/day/ square foot
----------------------	---	--

(xxx)

Density

1 kilo Newton cubic metre (KN/m³) = 6.3654 pounds/cubic feet

Pressure

1 kilo Pascal (kPa) = 20.886 pounds/square feet

Mass

1 Kilogram (Kg) = 2.2 pounds (lbs)

1 Kilogram (Kg) = 1000 grams (gm)

1 gram (gm) = 1000 milligrams (mg)

1 milligram (mg) = 1000 micrograms (ug)

Other Commonly Used Abbreviations

<u>Unit</u>	<u>SI Symbol or Abbreviation</u>
milligrams per litre	mg/L
micrograms per litre	ug/L
milli-equivalents per litre	meq/L
millimetres per annum	mm/a
metres per annum	m/a
parts per million	ppm
parts per billion	ppb
per mil or parts per thousand	°/oo
delta	δ

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1.0 INTRODUCTION

SECTION 1.0 INTRODUCTIONTABLE OF CONTENTS

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1.0 INTRODUCTION

1.1 BACKGROUND

1.1.1 PHASE 4B AND OWMC'S FACILITIES DEVELOPMENT PROCESS

This Report documents a portion of the geoscience studies (which incorporates geology, hydrogeology, and geotechnics) carried out by Gartner Lee Limited as part of Phase 4B of the Ontario Waste Management Corporation's (OWMC) Facilities Development Process. Phase 4B involves detailed assessments of the Preferred Site and surrounding area based on several disciplines, including the geosciences. The Preferred Site and immediate vicinity are illustrated in Figure 1-1.

The specific objectives of Phase 4B are to:

1. Define the existing environmental conditions (baseline) of the preferred siting option,
2. Predict and assess potential risks and impacts that may be associated with the proposed facility design and operations,
3. Identify and develop appropriate mitigative measures to minimize the potential risks and impacts,
4. Predict and assess residual risks and impacts after mitigation,
5. Identify and develop monitoring and contingency programs that will be implemented to assess the effectiveness of the design and operations in minimizing risks and impacts, and

Township of West Lincoln, Regional Municipality of Niagara. Local Detail.



OWMC Ontario
Waste Management
Corporation



Preferred Site
Figure 1.1

6. Prepare documentation to meet the requirements of Ontario's Environmental Assessment Act.

Figure 1-2 illustrates how Phase 4B relates to the other Phases of the OWMC Site Assessment and Facilities Development Process. Earlier phases are documented in OWMC (1982, 1983a, 1983b, 1983c, 1984 and 1985).

This report documents the detailed Phase 4B geologic, hydrogeologic and geotechnical studies undertaken by Gartner Lee Limited (GLL) at the Preferred Site to better define the pre-facility (baseline) physical setting.

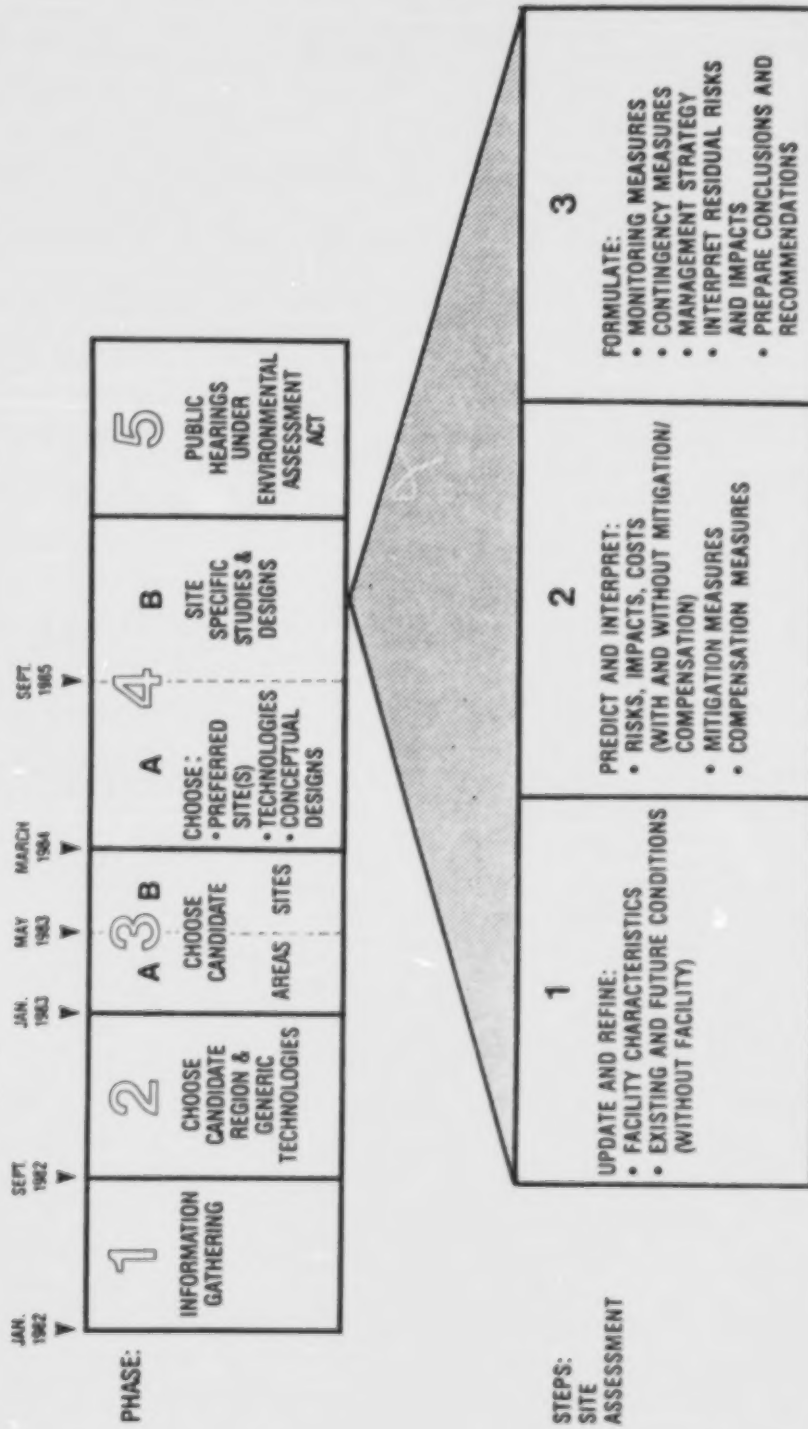
1.1.2 PREVIOUS GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL STUDIES

Geologic, hydrogeologic and geotechnical studies completed during the earlier phases of the site selection process, are briefly summarized below to provide the reader with a general appreciation of the role played by the geoscience disciplines in the selection of the Preferred Site.

The OWMC site selection process is guided by three fundamental goals, which in order of importance are to:

- (1) minimize risk to human health;
- (2) minimize environmental impacts; and
- (3) minimize financial costs to OWMC and the people of Ontario.

The geoscience studies have been guided primarily by the first goal, to minimize risk to human health. The link to human



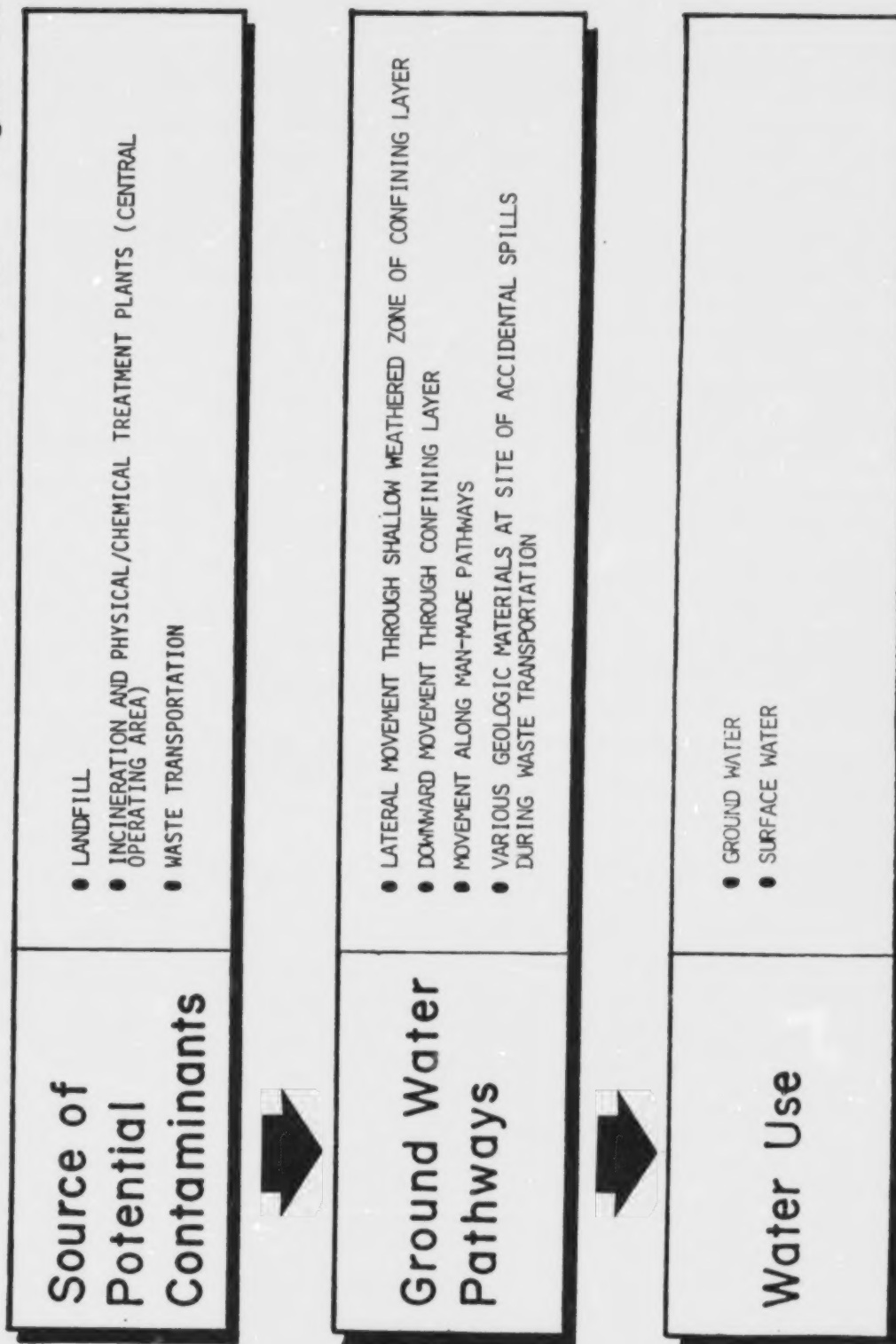
health stems from the possibility of contaminants moving from the proposed facilities through the subsurface into underlying local aquifers used for water supply purposes (Figure 1-3). Similarly, contaminants may follow ground water flow paths and discharge to local surface water courses, resulting in a potential effect on both human health (via direct contact with the surface water or indirectly through use of the water for crop irrigation or livestock watering) and the environment (aquatic life). Consequently, emphasis during the site selection process was placed on finding a site which has the potential to naturally retard the migration of contaminants which may be released from the proposed facilities (provide a second level of protection without reliance on engineered devices).

Areas underlain by thick, silt-clay soils which exhibit lateral and vertical textural and stratigraphic uniformity are considered to have the greatest potential to provide for the natural containment of contaminants (GLAL, 1983). Contaminant movement through such soils is predictably slow, thus maximizing the time available for contaminant degradation and interaction with the soils, and response time to carry out mitigative measures, if required.

The methodology employed during the initial three phases (Phase 1, Phase 2 and Phase 3) of the site selection process essentially involved:

- the analysis of the geologic setting of the area under consideration, at progressively larger scales (Phase 1 and Phase 2 - 1:250,000, Phase 3A - 1:50,000, Phase 3B - 1:10,000);

GROUND WATER PATHWAYS AND WATER USE Figure 1-3



- the division of the study area into smaller land areas based on geologic features or conditions, with the boundaries of each land area roughly corresponding to the maximum areal extent of the identified feature;
- the grouping and ranking of the smaller land areas in accordance with each area's potential to provide a high degree of natural containment of contaminants.

Table 1-1 summarizes the major geoscience activities, results and recommendations during the initial three phases of the site selection process.

Phase 4A of the site selection process involved the comparison of the various siting options for the purpose of identifying a preferred option. A siting option refers to a single site or a combination of sites required to accommodate the three major components of OWMC's proposed facility (incineration plant, physical/-chemical treatment plant and engineered landfill). The steps followed during this phase included:

- the identification of geoscience factors which could be used in the collection of field data and in the identification of the scope and content of potential problems associated with facility development and operation;
- the collection, compilation and analysis of technical information on the eight candidate sites to describe existing site conditions; and
- the refinement and comparison of siting options through the application of the geoscience factors.

TABLE 1-1: SITE SELECTION PROCESS - GEOLOGIC/HYDROGEOLOGIC ROLE

PHASE 1 AND PHASE 2: NARROW THE SEARCH TO A GEOGRAPHIC REGION IN ONTARIO		
Major Activities Undertaken	Results and Recommendations	Reports
major geologic/hydrogeologic features of southern Ontario identified, mapped (scale of 1:250,000) and described.	- a total of 261 regions were delineated and grouped into 6 hydrogeologic zones. - zone 1 and 2 lands may naturally restrict potential contaminant movement	GLAL, 1982a; 1982b
DPMC decision to focus future study on Zone 1 and 2 lands within the Golden Horseshoe (DPMC, 1982; 1983a)		
PHASE 3A: IDENTIFY CANDIDATE AREAS SUITABLE FOR EACH FACILITY COMPONENT WITHIN THE GOLDEN HORSESHOE		
documentation of hydrogeologic considerations to facility siting to provide guidance for the selection of priority areas of study	- areas underlain by the deepest, most consistent fine textured soils be given the highest priority of study. for an engineered landfill, areas of less than about 10 m of fine textured soils should not be considered and a higher degree of confidence would be realized as soil thickness increases. - for a treatment facility and incinerator areas underlain by less than about 10 m of fine textured soils could be considered but more detailed site investigation would be required.	GLAL, 1983
desk top analysis of the geology/hydrogeology of Zone 1 and 2 lands of the Golden Horseshoe at a scale of 1:50,000	- a total of 25 "Geologic Areas" and 65 smaller subareas were identified and grouped into a 4 category classification system - category 1 and 2 lands were assigned the highest priority for future study	GLAL, 1984a
DPMC decision to study only Category 1 and 2 lands. The search for an engineered landfill or fully integrated facility was to focus in areas underlain by at least 20 m of the fine textured soils and for a physical chemical plant and incinerator in areas underlain by at least 10 m of such soils. A total of 20 candidate areas were identified. (DPMC, 1983b; 1983c).		
PHASE 3B: IDENTIFY CANDIDATE SITES WITHIN CANDIDATE AREAS		
- preliminary analysis of geology, hydrogeology, surface drainage and physical terrain conditions - preparation of physical resource maps (constraint maps) at a scale of 1:50,000 - progressive refinement of data base for 90 site areas and 16 potential sites at a scale of 1:10,000	- identification of 10 physical resource factors and recommendation that portions of candidate areas containing "surface granular soil", "stream course", "floodplain", "wetland", "drumlin (Niagara)", "drumlin field" and "moraine" be considered as exclusionary. 38 site areas may potentially be considered for an integrated facility or landfill (12 ranked as 'Level 1', 14 ranked as 'Level 2', 12 ranked as 'Level 3'). 52 site areas may potentially be considered for a chemical treatment plant or incinerator (16 ranked as 'Level 1', 27 ranked as 'Level 2', 9 ranked as 'Level 3'). - portions of site areas containing constraints (flood plains, stream courses, spoil piles and moraines) should be considered exclusionary for facility placement. - of the 17 siting options (includes the 16 potential sites) 2 were ranked as 'Level 1', 5 as 'Level 2' and 9 as 'Level 3'. - Only one site (P-36) was ranked as 'major constraint' and should be excluded based on hydrogeology.	GLAL 1984b
DPMC accepted the site selection team's recommendation to focus future study on the eight candidate sites which were identified (DPMC, 1984).		

(Modified from GLAL, 1985)

The role of the geoscience consultant during Phase 4A is documented in a nine volume set of reports which includes the main report and eight technical appendices (GLAL, 1985). The main report describes the methodology used in the comparative evaluation of the siting options and the results of the comparative evaluation. The eight separately bound technical appendices describe the geologic, hydrogeologic and geotechnical setting at the eight candidate sites.

1.2 OBJECTIVES

For the geosciences, Gartner Lee Limited's (GLL) Phase 4B studies have focused on:

1. Establishing baseline conditions for the Preferred Site (this report),
2. Providing required input to OWMC's engineering consultants for conceptual facilities design (GLL, 1987a; 1987b),
3. Assessing potential ground water impacts from the Central Operating Area, (GLL, 1987c),
4. Assessing, mitigating and comparing various engineered landfill design concepts as input to OWMC's selection of the shallow entombed landfill (GLL, 1987b),
5. Assessing potential ground water impacts from the shallow entombed landfill (GLL, 1987d), and
6. Developing an overall ground water management plan through monitoring, mitigation and contingency strategies (GLL, 1987e).

Figure 1-4 illustrates how this Report fits into GLL's Phase 4B studies.

The major objective of this Report was to establish pre-facility conditions (baseline conditions) at OWMC's Preferred Site to be used as input to the other GLL Phase 4B impact and design related studies listed above. This baseline information will also provide the basis for comparison to future performance monitoring.

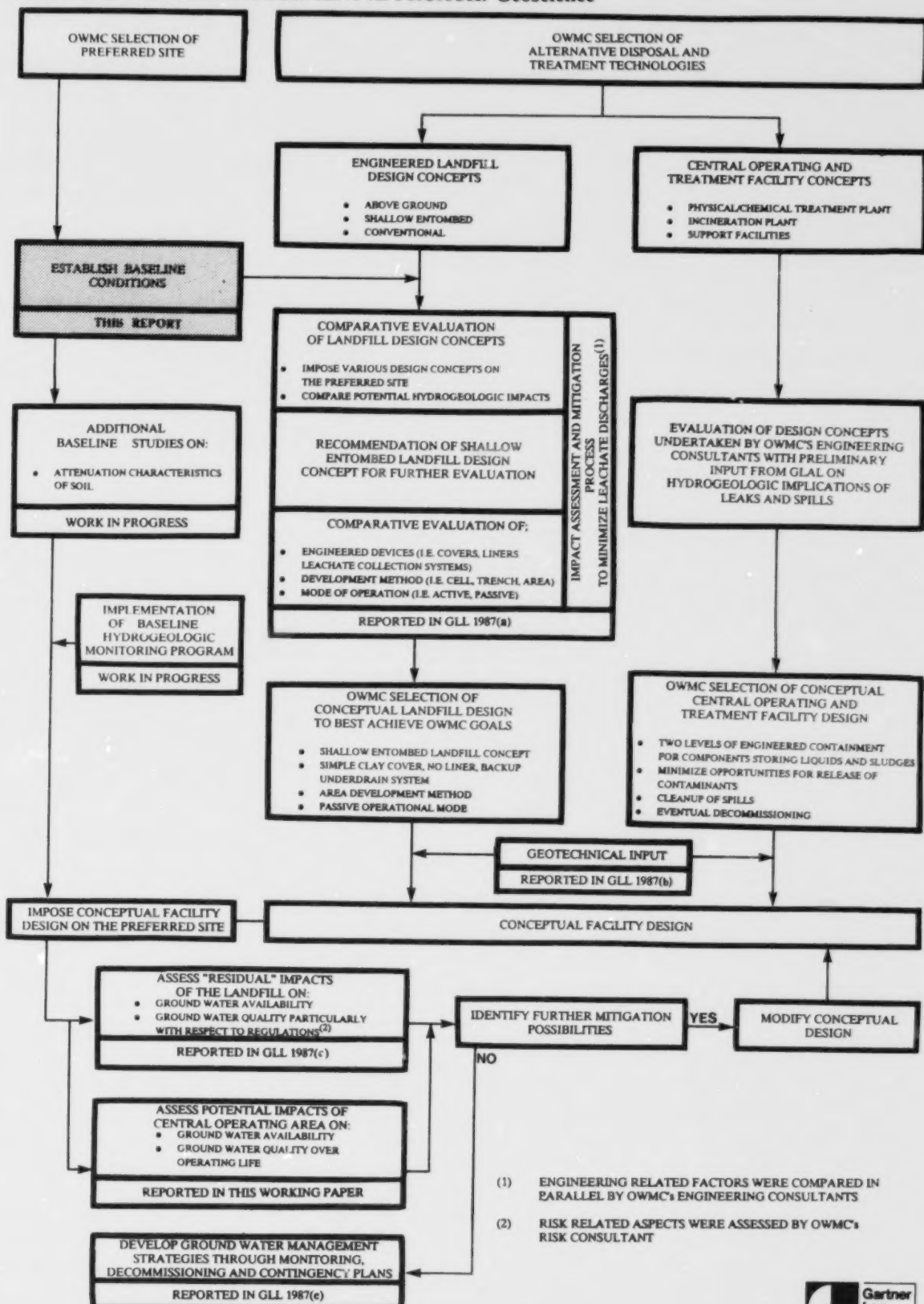
A secondary objective of the study program was the confirmation of the Phase 4A interpretation of the physical setting at the Preferred Site. OWMC's selection of the Preferred Site was significantly influenced by the presence of favourable and predictable geologic conditions at the site. Based on the Phase 4A study, the site is underlain by a 30 to 35 m thick layer of silt-clay which is continuous and exhibits lateral and vertical textural uniformity. Ground water and solute movement through these soils is predictably slow.

1.3 APPROACH AND SCOPE OF STUDIES

The Phase 4B geoscience study program combines investigations in geology, geophysics, physical hydrogeology, geochemistry, ground water use and geotechnics. The investigations for each discipline entailed:

- development of a detailed work plan and protocols for field studies;

FIGURE 1-4
PHASE 4B: IMPACT ASSESSMENT APPROACH: Geoscience



- field studies which included both surface and subsurface work such as drilling, testing, sampling, monitoring and the interviewing of local residents, agency and university personnel familiar with the area
- laboratory testing;
- data compilation, analysis, interpretation and reporting.

The Phase 4B geoscience study program is briefly described below. Details on the investigations undertaken for each discipline are presented in the applicable sections of the report (e.g. Section 2.0 "Geology").

1.3.1 WORK PLAN AND PROTOCOLS

A work plan was initially developed which identified the scope and details of each activity proposed for the Phase 4B geoscience study program (GLAL, 1986a). The work plan was a guide to the various activities and tasks undertaken during the program. The work plan is divided into nine activities:

- (1) Phase 4B planning;
- (2) geophysics;
- (3) drilling related work;
- (4) geology;
- (5) geotechnics;
- (6) hydrogeology;
- (7) water use survey;
- (8) geochemistry; and
- (9) geoscience analysis.

Each of these activities was further divided into a series of tasks. The activities are briefly described below.

Planning for the Phase 4B geoscience study program included preparation of the work plan and protocols (GLAL, 1986a). The protocols consist of procedural directives to guide field staff in such activities as drilling, geologic sampling, installation of monitors, ground water sampling and sample analysis. They ensured uniformity between field crews, provided descriptions of methods and techniques used, and served as a means of quality control. The protocols are presented in full in Appendix A and Appendix B of the report.

The geophysics activity involved the completion of a seismic reflection/refraction survey to define subsurface conditions between boreholes and beyond the site boundaries. The option of a shallow penetrating electromagnetic survey was initially proposed to detect shallow subsurface anomalies that might have been attributed to soil textural changes if they were encountered. However, this survey was not undertaken because the drilling and shallow investigation program identified uniform soil conditions at the site.

The drilling and related work activity included the various drilling, sampling and monitor installation tasks.

The geology activity which provided direction for the collection of data for the other activities and for placement of monitors consisted of:

- review of existing data collected during earlier reporting phases;
- logging interpretation and supervision;

- site terrain and Quaternary studies; and
- analysis, interpretation and reporting.

The geotechnical activity provided input to the conceptual design of the proposed facilities. This activity was tailored to interface with the other geoscience programs and relied on borehole logging and the analysis of geotechnical samples to define index properties, soil shear strengths, and consolidation parameters for the relevant soils.

The hydrogeology activity primarily addressed ground water flow directions, velocities and quantities. Major tasks under this activity included:

- review of existing hydrogeologic data collected during earlier study phases;
- hydraulic conductivity testing (slug tests, pumping tests, packer tests, recovery tests and laboratory tests);
- water level monitoring;
- computer modelling;
- preparation of a water budget; and
- analysis, interpretation and reporting.

The water use survey activity involved the collection of information on wells, cisterns and water use by a house to house survey. This information was supplemented with data from the

Phase 4A water use study and water well records maintained on file by the MOE. The study area included the site and site vicinity to about 2 km north of the site and between the site and the Welland River (the direction of ground water flow in the underlying bedrock aquifer).

The geochemistry activity entailed the:

- compilation of existing ground water quality data; and
- collection of additional ground water quality data by collecting water samples from on-site monitors and soil cores for laboratory analysis.

The geoscience analysis activity included project management and administration, and the preparation of this report.

1.3.2 FIELD STUDIES AND LABORATORY ANALYSES

The various sources of data used in completion of the Phase 4B geoscience study program are summarized in Table 1-2. Field stations and drilling locations are presented on the site plan, Figure 1-5. Field activities, which included the geophysical survey, drilling, sampling, monitor installation and hydraulic conductivity testing were initiated in November 1985 and essentially completed by June 1986. Laboratory analyses were undertaken over the interval January to June 1986. Water level monitoring data presented in this report are current to October 1986. Future monitoring results (post 1986 period) will be presented in separate reports.

1.3.3 DATA COMPILATION, ANALYSES, INTERPRETATION AND REPORTING

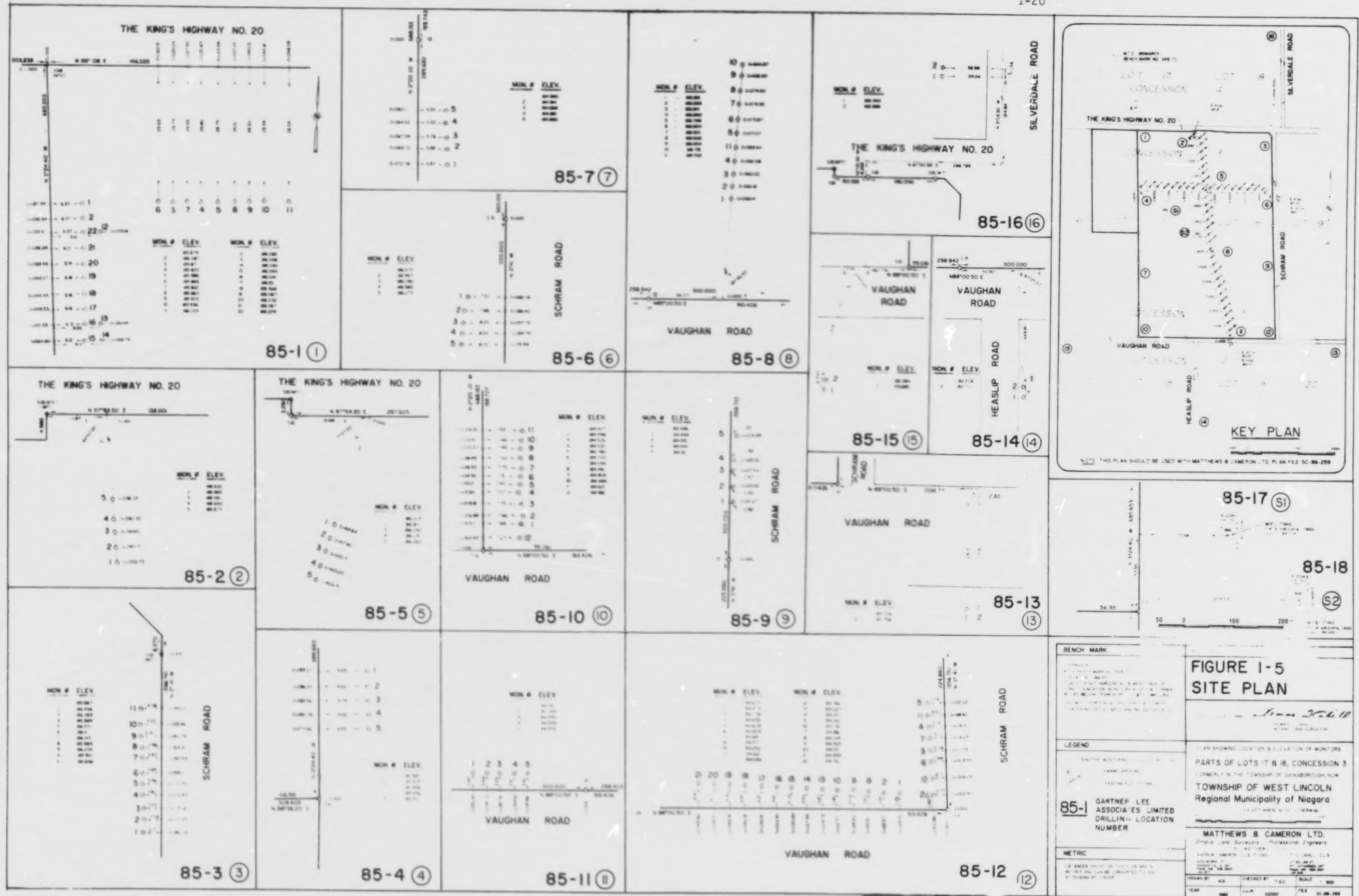
Data handling and compilation was greatly facilitated through

TABLE 1-2: PHASE 4B GEOSCIENCE STUDY PROGRAM

DISCIPLINE AND PROGRAM CONTENT	INVESTIGATION TECHNIQUE
GEOLOGY	
● terrain features ● stratigraphy ● public and agency contacts ● physical characteristics of geologic units ● thickness of units	● incorporate existing data from previous study phases ● public and agency contacts ● field survey, geophysical survey, hand augering and shallow trenching ● boreholes - collection of 586 m of overburden and 112m of bedrock core at 12 on-site and 4 off-site locations ● geotechnical laboratory studies
PHYSICAL HYDROGEOLOGY	
● hydrostratigraphy ● hydrogeologic properties of geologic units ● direction and rate of ground water movement ● water budget	● incorporate existing studies ● installation of a total of 91 water level monitors at 12 on-site and 4 off-site locations (includes 14 pneumatic piezometers, 16 standpipes and 61 standard piezometers) ● hydraulic testing including: - 65 slug tests; - 20 packer tests at two sites; - 17 laboratory tests of vertical and horizontal hydraulic conductivity; and - 1 pump test ● monthly water level monitoring ● two dimensional ground water flow modelling ● water budget analysis
GEOCHEMISTRY	
● characterization of existing (pre-facility) inorganic and isotopic ground water chemistry ● interpretation of data with respect to probable depth of active ground water flow in the shallow subsurface (weathered silt and clay)	● review of existing data ● sampling and laboratory analysis of ground water samples from 36 monitors in the weathered silt and clay, unweathered silt and clay and bedrock for detailed inorganic and general chemistry, dissolved methane and oxygen-18, deuterium and tritium isotopes

TABLE 1-2 (continued)

DISCIPLINE AND PROGRAM CONTENT	INVESTIGATION TECHNIQUE
GEOCHEMISTRY (cont'd)	
• determine if downward ground water flow through the weathered overburden is sufficiently slow that ground waters at depth are very old and solute transport processes are slow and predictable	• collection of 2 ground water samples from the unweathered silt and clay for radiocarbon (carbon-14) age dating • collection of 25 samples representing depth profiles at two locations for pore water squeezing and analysis of the pore water for oxygen-18 and deuterium isotopes • one dimensional ground water flow and solute transport modelling of oxygen-18 and deuterium isotope results
WATER USE	
• existing water use • projected water use	• house to house survey (survey forms) • water well records • discussions with socio-economic consultant
GEOTECHNICAL ASSESSMENT	
• physical properties of geologic materials for purposes of assessing soil slope stability for landfill soil foundation considerations and operational considerations respecting excavation and trafficability of soils (analysis results are provided in GLL, 1987a)	• incorporate existing studies • geologic logs and interpretation • soil sampling • physical hydrogeologic interpretation • laboratory analyses and testing, including: - moisture content (600+) samples, - liquid and plastic limits (26), - specific gravity (6), - unit weight (62), - consolidation test (6), - compaction test (2), - laboratory vane (40), - grainsize analyses (28), - unconfined compression test (19), - unconsolidated, undrained, triaxial test (11), - consolidated, undrained, triaxial test with pore pressure measurements (3 sets of 3) - direct shear test (6 sets of 3)



the use of standardized record forms. Under certain circumstances, particularly where it was necessary to store and handle large volumes of data, such as that collected during long-term water level monitoring, 'spread sheet' type computer programs were used.

Data analysis consisted of:

- preliminary review of the data and resolution of any discrepancies;
- transfer and tabulation of the data to working maps, and summary forms, and the preparation of cross sections and graphs; and
- processing of the data using standard analytical techniques to render the data into a usable form (e.g. conversion of water levels to their equivalent elevations and the calculation of aquifer coefficients from test results).

Interpretations utilized the processed data and were closely coordinated between the various geoscience disciplines. For example, the geotechnical interpretation required input from both the project geologist and hydrogeologist.

Findings are documented in the applicable sections of this report. The text is supported, where useful, by tables, graphs and figures. Data summaries are provided in the appendices of the report along with methodologies.

1.4 REPORT ORGANIZATION

The Phase 4B geoscience study results are contained within a three volume set consisting of a summary report which defines the pre-facility physical setting and two volumes of technical appendices. The reader should consult the Summary Table of Contents for general information on the report's organization. A separate, more detailed Table of Contents is provided for each section of the report and the appendices. Definitions of commonly used terms are provided in the Glossary of Terms (Section 8.0).

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2.0 GEOLOGY

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2.0 GEOLOGY

2.1 INTRODUCTION

2.1.1 PURPOSE AND SCOPE

The geology and terrain features of OWMC's Preferred Site are described in this section. The geologic component of the Phase 4B geoscience study program was directed towards the verification of the geologic setting of the Preferred Site as previously described in the Phase 4A Technical Appendix LF-9C (GLAL, 1985). The interpretation of the geologic setting contained herein, builds on the data base compiled during previous phases of OWMC's site selection process.

The geologic studies were closely coordinated with the geotechnical analysis (Section 6.0) and relied on the geophysical survey (Appendix D) to provide stratigraphic control between boreholes.

Terrain features are described in Section 2.2, the Quaternary geology in Section 2.3, and the bedrock geology and overburden thickness in Sections 2.4 and 2.5, respectively.

2.1.2 BACKGROUND

The geologic component of the Phase 4B geoscience study program is the latest and most detailed of a series of studies investigating the geology of progressively smaller study areas identified by OWMC. The geologic descriptions and interpretations provided in these reports formed the basis for the assessment of hydrogeologic and geotechnical conditions during these earlier studies. A complete listing of these earlier studies, is provided in Section 1.1.2.

The geologic setting of the Preferred Site, as described in the Phase 4A Site Selection report (GLAL, 1985), consists of three silt-clay units with a combined thickness of approximately 30 m across the site. No significant or continuous granular zones were identified within the silt-clay sequence and the sequence was considered to exhibit a high degree of textural uniformity.

The geologic component of the Phase 4B geoscience study program was designed to verify the interpretation of the geologic setting of the Preferred Site. The results of this study will also provide the necessary geologic control for assessing geotechnical, hydrogeologic and geochemical conditions.

2.1.3 METHODOLOGY

Considerable additional geologic information was collected during the Phase 4B field program. Major sources of information used in this study include:

- the drilling component which facilitated the preparation of detailed geologic logs prepared after interpreting continuous core samples from the stratigraphic boreholes;
- laboratory testing results;
- shallow test trenches, hand auger holes and soil probe holes; and
- geophysical survey results.

The field program provided detailed information on the character and continuity of the geologic materials. The program

is briefly described below. Actual drilling and sampling procedures are presented in Appendix A1.

The drilling component involved the collection of continuous samples from boreholes completed at 12 on-site and 4 off-site locations. The average depth of the stratigraphic boreholes is about 40 m. A second adjacent borehole was completed at the on-site locations to obtain samples for assessment of the geotechnical properties of the materials. The on-site borehole locations are shown in Figure 2-1 (pocket at back of the report). The off-site borehole locations are shown in the site plan (Figure 1-4). The samples were photographed, described, placed in suitable containers and taken to an on-site heated storage facility. Detailed borehole logs were prepared based on the field descriptions, geotechnical test results and on subsequent reexamination of the samples in storage. The borehole logs are presented in Appendix C1 and the geotechnical laboratory test results are provided in Appendix E1.

Two additional on-site boreholes (identified as locations 85-17 and 85-18 in Figure 2-1) were completed to investigate two perennially wet depressions on site. Continuous samples were collected from these boreholes to a depth of about 10 m. These logs are also presented in Appendix C1.

Three shallow trenches, about 2 m deep, were dug on site (Figure 2-1) to investigate the ridge and swale topography. In addition, a detailed "walk-over" survey was conducted on the site which combined shallow hand augering and soil probing. A description of the stratigraphy and structure of the observed materials is provided in Appendix C1. The locations of the field stations are also shown in Figure 2-1.

A seismic reflection survey was undertaken to:

- determine the continuity of subsurface overburden conditions between borehole locations on-site and beyond the Preferred Site boundaries; and
- identify anomalous subsurface conditions for selecting off-site or on-site drilling locations.

A detailed description of the seismic survey is presented in Appendix D.

Analysis and interpretation of the results of the field program entailed preparation of detailed geologic borehole logs and field station descriptions, geologic cross-sections and surficial mapping. In addition, oil and gas well, and water well information presented in Appendices C4 and H1, respectively, was reviewed and updated.

2.2 TERRAIN FEATURES

2.2.1 INTRODUCTION

OWMC's Preferred Site is situated on a broad glaciolacustrine lake plain, commonly referred to as the Haldimand Clay Plain (Chapman and Putnam, 1984). The surface topography is relatively flat with relief being limited to a series of shallow ridges and drainage swales. Virtually the entire 124 ha of the site occurs between surface elevations of 183 and 186 m.a.s.l. No major topographic features are evident on the site.

The site is situated in the watershed of the Welland River and is located slightly over a kilometre south of the surface

water drainage divide between the Welland River and Twenty Mile Creek watersheds. Stream gradients are extremely low and the local drainage network is poorly developed. There are numerous low wet swales on and around the site. Many of these swales retain standing water throughout the year and support the growth of wetland vegetation. A more detailed discussion of the ridge and swale "micro-relief" on the site is presented in the following section. A detailed description of the surface drainage network is provided in the surface water report (M.M. Dillon Limited, 1987).

2.2.2 MICRO-RELIEF FEATURES

The Haldimand Clay Plain in the site vicinity displays a washboard-type of surface micro-relief. The washboard pattern is present as a series of sub-parallel ridges and swales trending generally north-northwest to south-southeast. Relief averages less than one metre. The linear trend is not clearly noticeable on the surface but is apparent on airphotographs (Figure 2-2).

The exact origin of the swales is not known and has been the subject of several theories (Loken and Leahy, 1964; Henderson, 1967; Mollard, 1975; Feenstra, 1981b). Two shallow boreholes, two deep boreholes, three shallow trenches and several dozen hand auger or soil probe holes were completed in or adjacent to the swales to investigate their physical structure. Data from the present study support the hypothesis presented by Henderson (1967), namely that the swales and ridges may have been formed as a result of the deformation of soft surface sediments following the decline in proglacial lake levels and the grounding of the ice-shelf on the lake bottom.

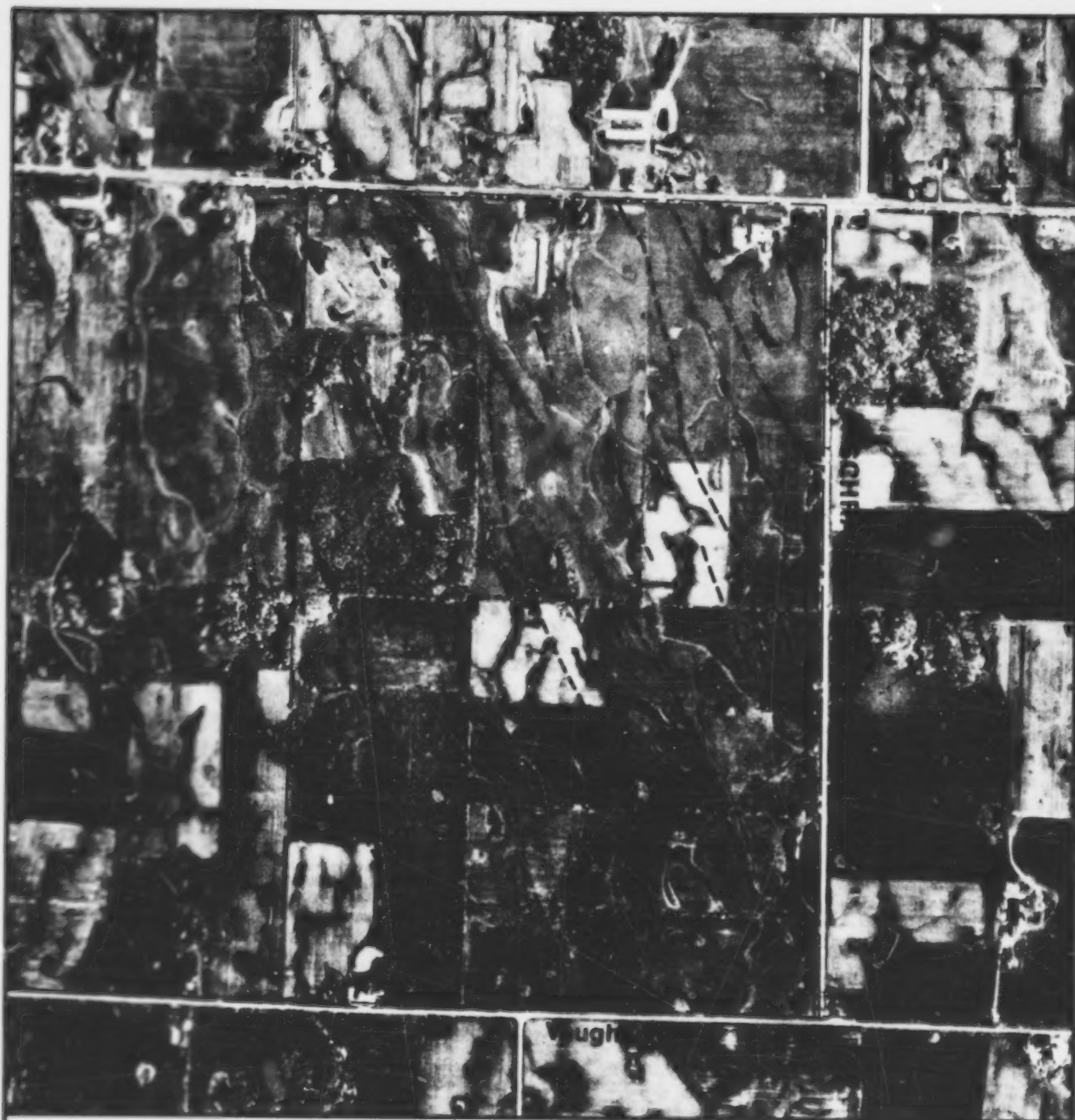


FIGURE 2-2
MICO-RELIEF FEATURES
(dashed line denotes crest of ridge)

Legend

— Boundary of Preferred Site



Scale 1 to 10,000

Two types of material were encountered in the deeper swales (Figure 2-3). Parts or all of these sediments were missing in the shallower swales. The upper material is a combination of decomposed organics and silt and clay. This material is commonly about 0.5 m in thickness, is soft, and contains many roots. The underlying material consists of a uniform grey silty clay. It is usually massive, rarely laminated and is rarely more than a metre in thickness. Both these materials are of soft to firm consistency and were wetter than the plastic limit. These materials referred to as "swale sediments" are derived from the pre-existing Upper Glaciolacustrine Unit.

The Upper Glaciolacustrine Unit described in Section 2.3, underlies these sediments. This unit is a silt and clay to clayey silt, is often laminated and usually contains rock clasts. It is usually of stiff consistency and is commonly wetter than the plastic limit. The physical differences between the swale sediments and the underlying Upper Glaciolacustrine Unit are generally distinctive as is the contact between them. In a few cases, the upper portion of the Upper Glaciolacustrine Unit was softened by standing water making the contact indistinct. Total thicknesses of the swale sediments are commonly 1 to 1.5 m. The maximum thickness of 2.5 m was encountered at borehole location 85-18 (Figure 2-1). The Upper Glaciolacustrine Unit underlying the swale sediments is similar to that encountered elsewhere on the site except that it is less desiccated and displayed few distinctive fractures.

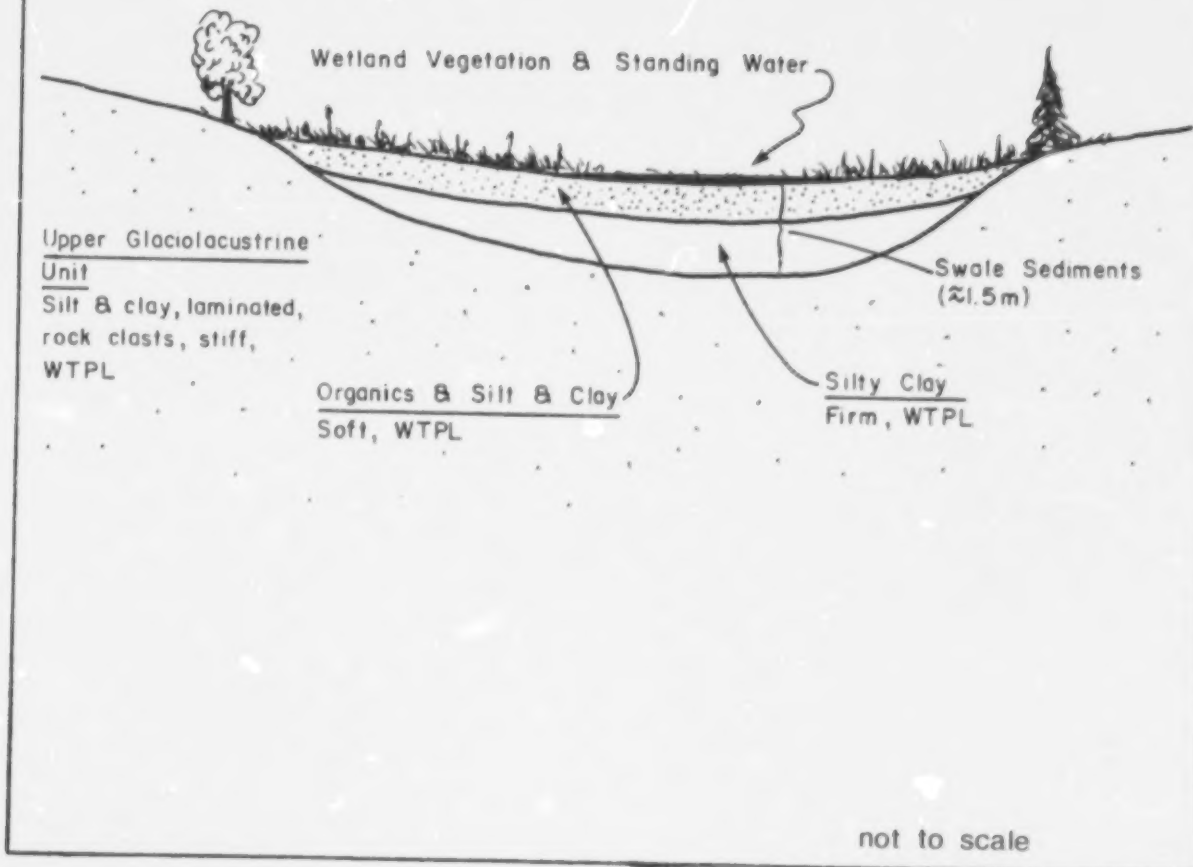
2.3 QUATERNARY GEOLOGY

2.3.1 INTRODUCTION

The Quaternary geology of the Niagara Region is well documented

FIGURE 2-3

Cross-Section Sketch Through A Typical Swale



and has been summarized in earlier DWMC studies (GLAL, 1984a, 1985). Major work in the region was published by Owen (1969, 1972) and Feenstra (1981b).

The major Quaternary geologic units in the Niagara Region which are identified and described in this report are shown in Figure 2-4. The four basic units, from surface to depth (youngest to oldest) are:

- (1) the Upper Glaciolacustrine Unit;
- (2) Halton Unit;
- (3) Lower Glaciolacustrine Unit; and
- (4) Lower Till.

For the most part, the unit names are similar to those used by Feenstra (1981). Table 2-1 presents the major stratigraphic units identified by Feenstra and the corresponding Phase 4A and Phase 4B stratigraphic terminology. Three cross-sections completed through the site are shown in Figures 2-5, 2-6 and 2-7 (Cross Section locations shown in Figure 2-1 in pocket of this volume). The general physical character and history of these units has been described in previous reporting (GLAL, 1984a; 1985).

The Lower Till in the area is a sandy silt to silt till which lies directly on bedrock. It is commonly one or two metres in thickness and is generally correlated to the Wentworth ice advance more than 14,000 years ago.

The overlying glaciolacustrine and till strata were deposited as a continuous geologic process. A large proglacial lake was established in the area with the withdrawal of the Wentworth ice. The sediments of the Lower Glaciolacustrine unit

FIGURE 2-4
 Cross-Section Sketch Through The Eastern Niagara Peninsula



Adapted from GLAL 1984a

NOT TO SCALE

TABLE 2-1: GEOLOGIC UNITS

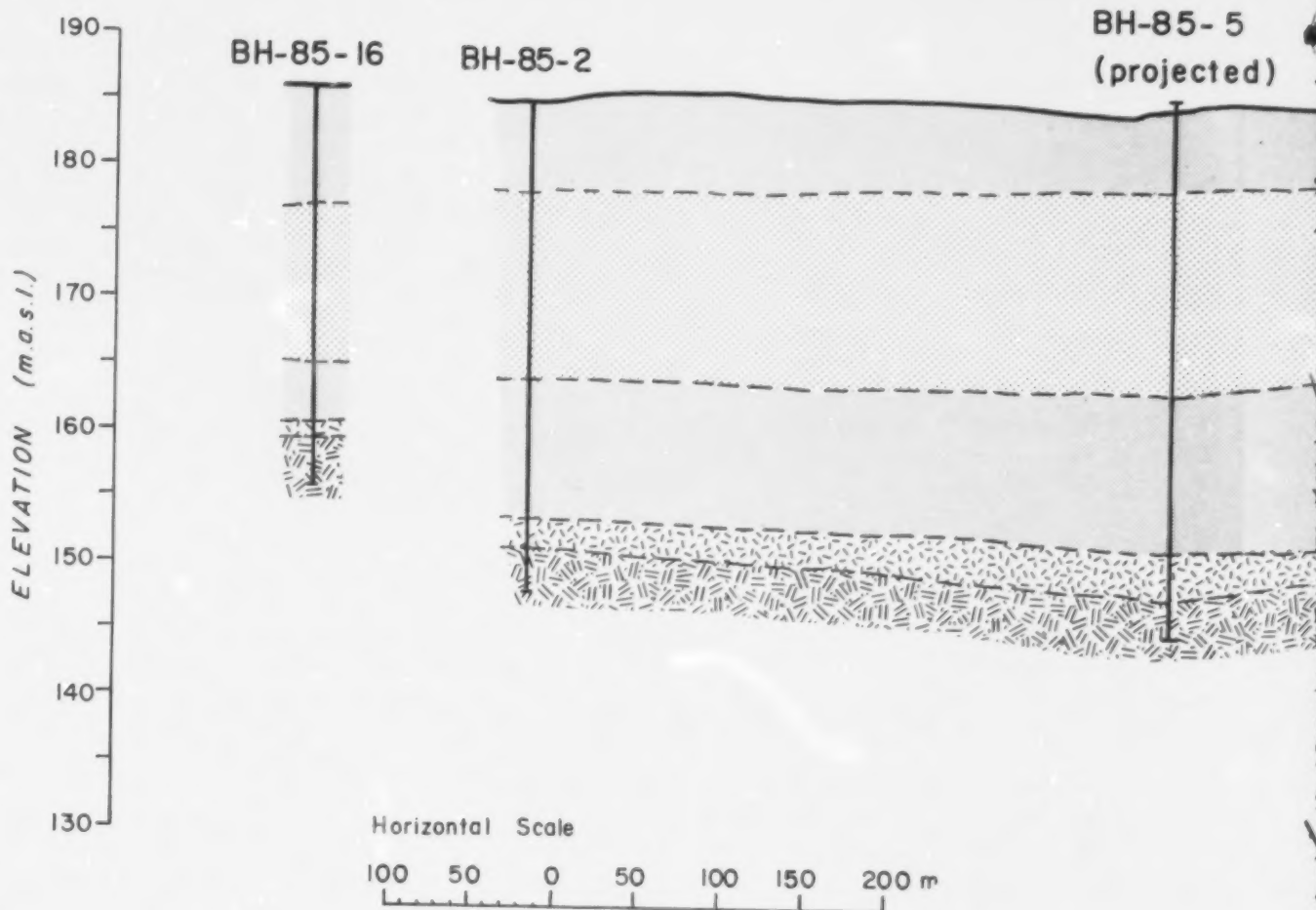
FEENSTRA (1981b)	<u>GEOLOGIC UNITS</u>	
	PHASE 4A	PHASE 4B
Upper Glaciolacustrine Unit (silt-clay)	Upper Glaciolacustrine Unit (silt-clay)	Upper Glaciolacustrine Unit (silt-clay)
Halton Till (silt-clay till)	Halton Till (silt-clay till)	Halton Unit (silt-clay and silt-clay till)
Lower Glaciolacustrine Unit (silt-clay)	Lower Glaciolacustrine Unit (silt-clay)	Lower Glaciolacustrine Unit (silt-clay)
Lower Till (sand and silt-till)	Lower Till (sand and silt till)	Lower Till (sand and silt-till)
Guelph Formation (dolostone)		

A

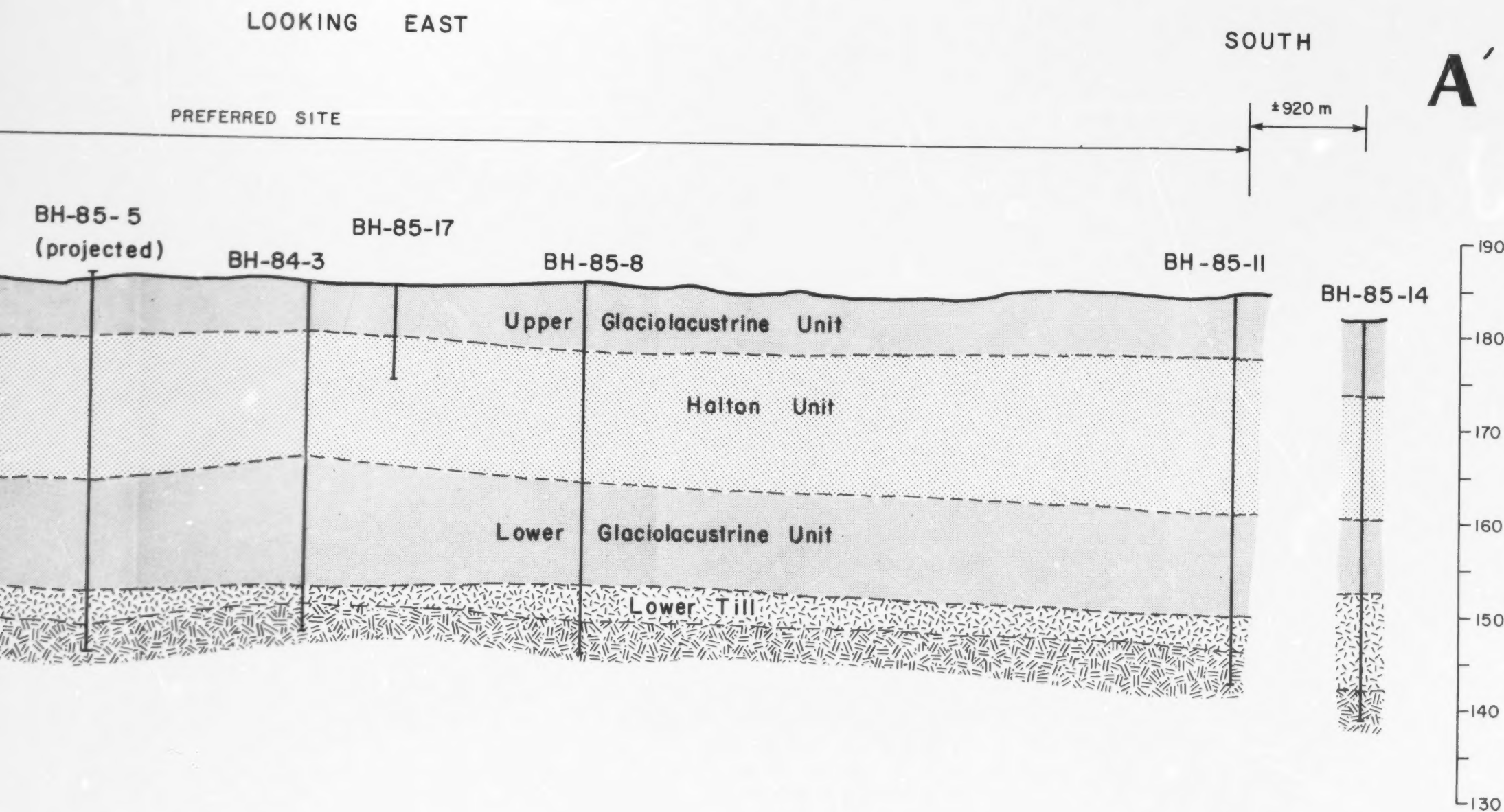
NORTH

± 1500 m

PR



Vertical Exaggeration 8x



OWMC Ontario Waste Management Corporation

Consultant



Legend:

- Glaciolacustrine Sediments: clayey silt to silty clay, occasional clast, commonly laminated
- Till & Glaciolacustrine Sediments (Intermixed): clayey silt, occasional clast, massive to poorly laminated
- Till: sand and silt, gravelly, massive, occasional sand inclusion
- Dolostone: fine grained, occasional shale laminae, occasional vug

BH-85-2 Gartner Lee Associates Limited borehole (with year and number)

Borehole: with top, bottom and geological contacts noted

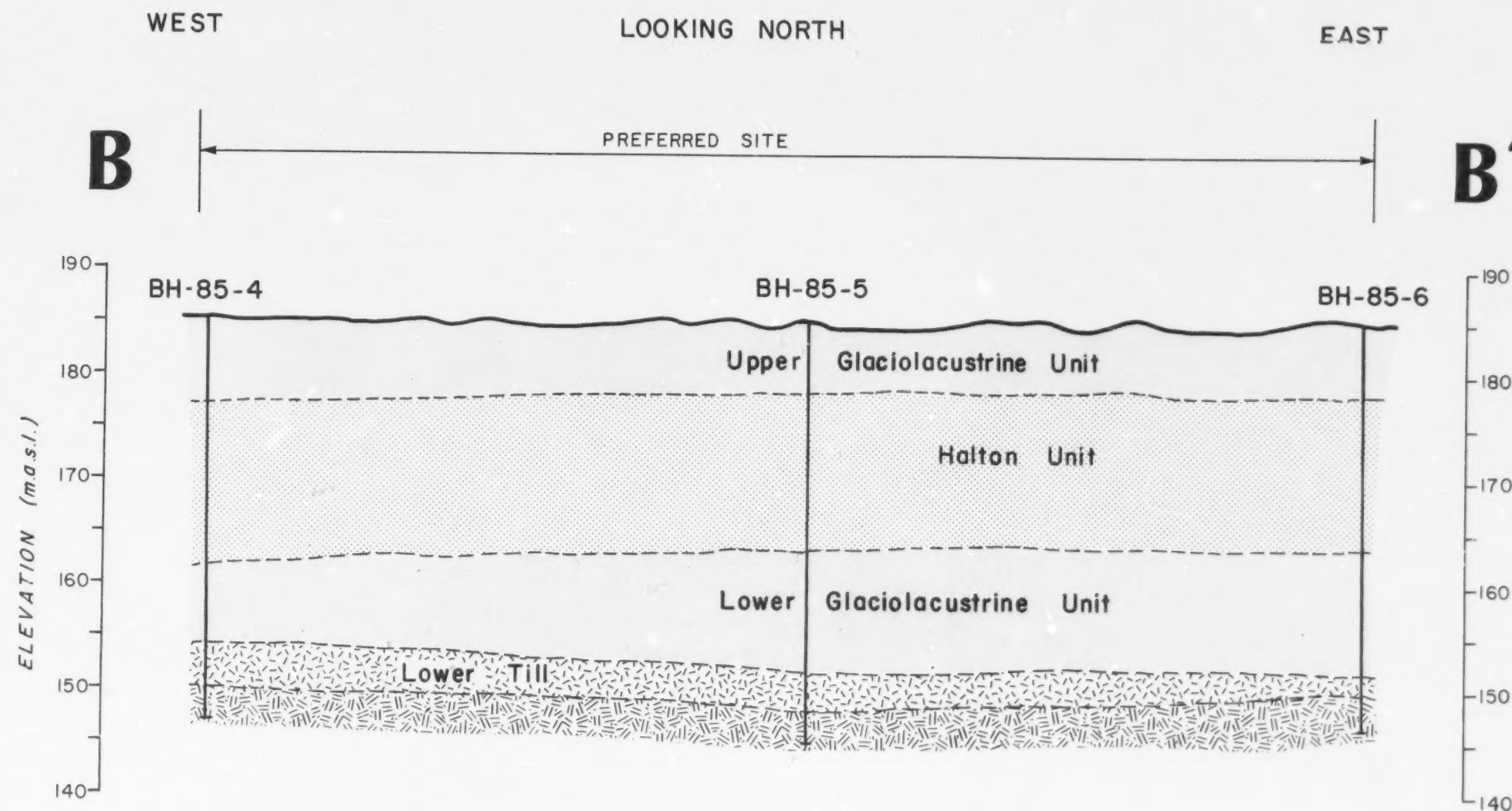
Notes:

Off-site boreholes 85-14 and 85-16 have been placed at the ends of the cross-section to demonstrate the continuity of the subsurface units to distances approximately one km from the site. The distance from these boreholes to the Preferred Site is not plotted to scale on the cross-section

CROSS-SECTION A-A'

West Lincoln Township

Figure 2-5



Horizontal Scale

100 50 0 50 100 150 200 m

Vertical Exaggeration 8x

OWMC Ontario Waste Management Corporation

Consultant



Legend:

- Glaciolacustrine Sediments: clayey silt to silty clay, occasional clast, commonly laminated
- Till & Glaciolacustrine Sediments (Intermixed): clayey silt, occasional clast, massive to poorly laminated
- Till: sand and silt, gravelly, massive, occasional sand inclusion
- Dolostone: fine grained, occasional shale laminae, occasional vug

BH-85-5 Gartner Lee Associates Limited borehole (with year and number)



Borehole: with top, bottom and geological contacts noted

CROSS-SECTION B-B'

West Lincoln Township

Figure 2-6

Consultant



Legend:

-  Glaciolacustrine Sediments: clayey silt to silty clay, occasional clast, commonly laminated
-  Till & Glaciolacustrine Sediments (Intermixed): clayey silt, occasional clast, massive to poorly laminated
-  Till: sand and silt, gravelly, massive, occasional sand inclusion
-  Dolostone: fine grained, occasional shale laminae, occasional vug

BH-85-5 Gartner Lee Associates Limited borehole
(with year and number)



Borehole: with top, bottom and geological
contacts noted

CROSS-SECTION B-B'

West Lincoln Township

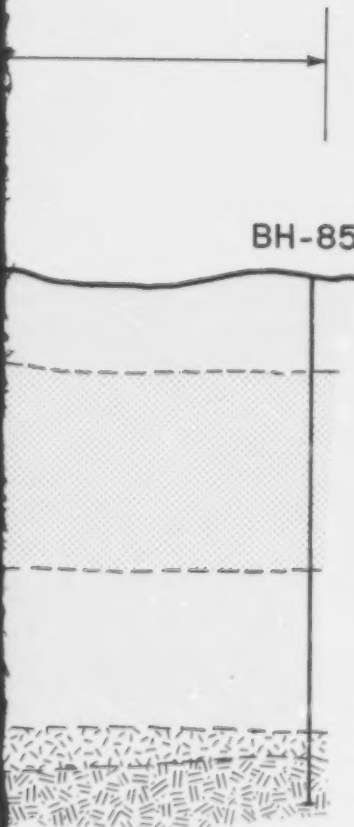
Figure 2-6

EAST

B'

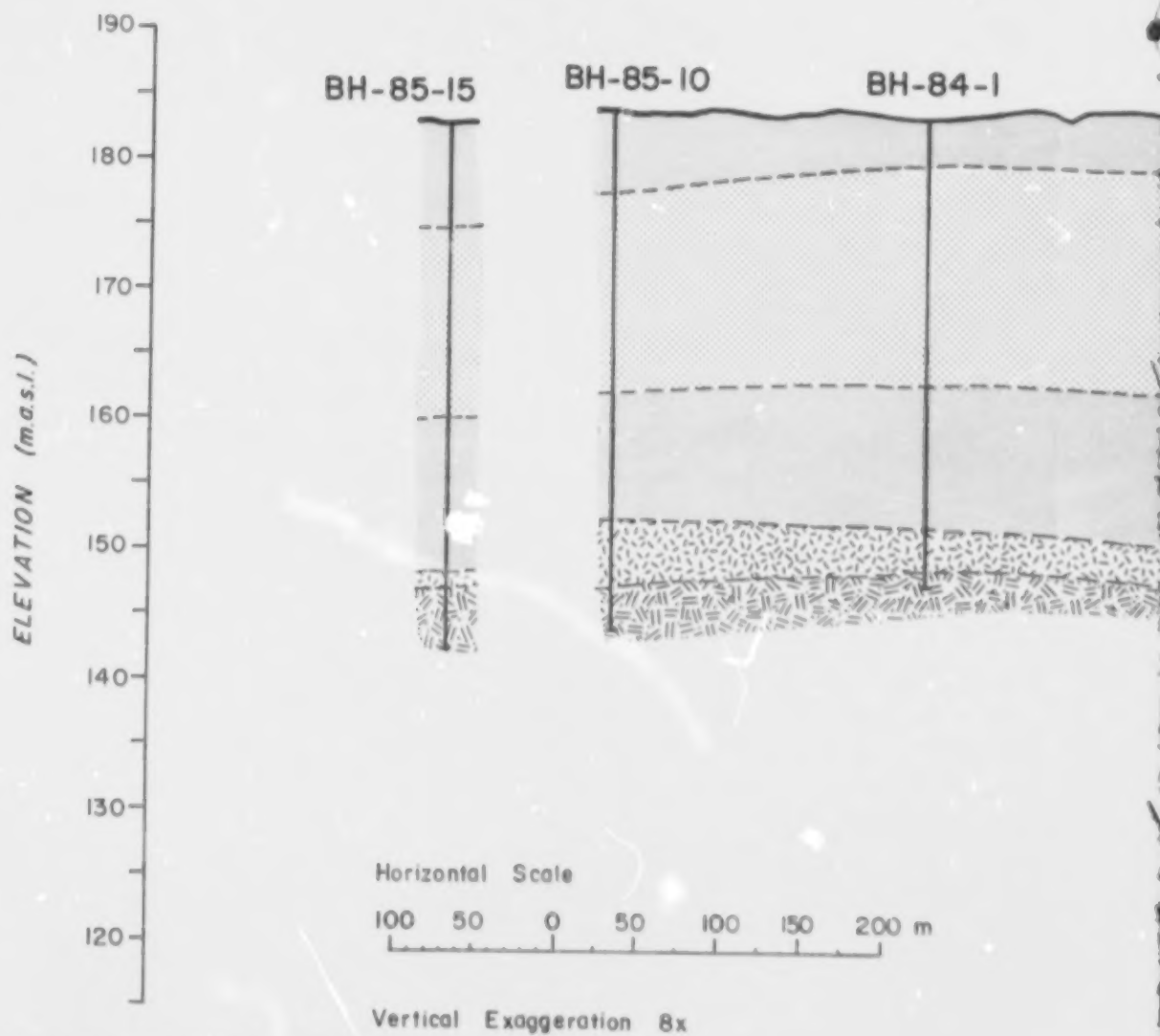
BH-85-6

190
180
170
160
150
140



C

PREP



Consultant



Legend:

- Glaciolacustrine Sediments: clayey silt to silty clay, occasional clast, commonly laminated
- Till & Glaciolacustrine Sediments (Intermixed): clayey silt, occasional clasts, massive to poorly laminated
- Till: sand and silt, gravelly, massive, occasional sand inclusion
- Dolostone: fine grained, occasional shale laminae, occasional vug

BH-84-1 Gartner Lee Associates Limited borehole
(with year and number)

Borehole: with top, bottom and geological contacts noted

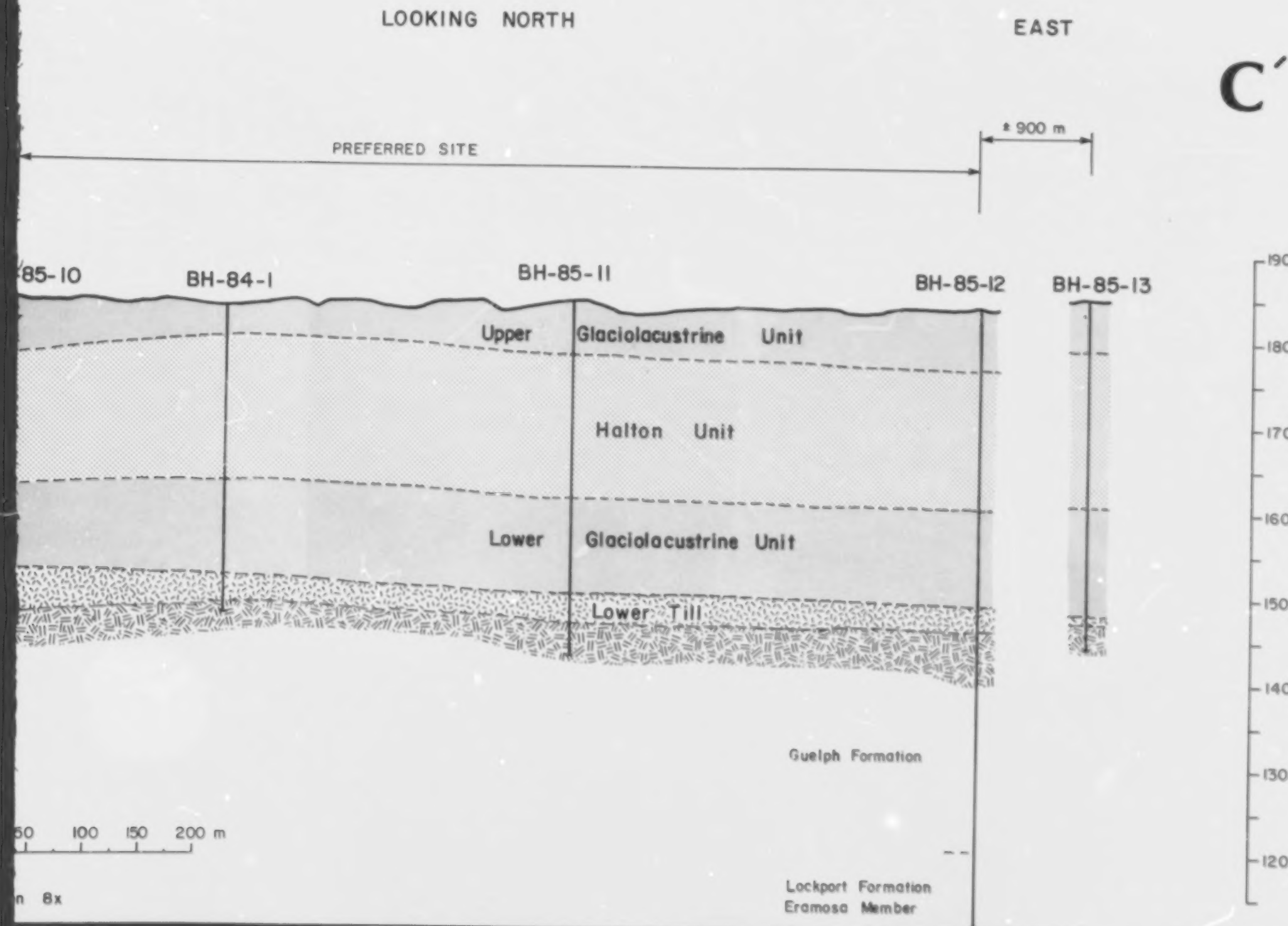
Notes:

Off-site boreholes 85-13 and 85-15 have been placed at the ends of the cross-section to demonstrate the continuity of the subsurface units to distances approximately one km from the site. The distance from these boreholes to the Preferred Site is not plotted to scale on the cross-section.

CROSS-SECTION C-C'

West Lincoln Township

Figure 2-7



were laid down in this lake. The ice then readvanced into the lake and deposited the Halton Unit. The lake was re-established as the Halton ice withdrew northward. The Upper Glaciolacustrine Unit was deposited in this late phase of the lake. The geology and landscape of the West Lincoln site has changed little since the proglacial lake drained more than 10,000 years ago.

The geologic component of the Phase 4B geoscience study program has confirmed the basic stratigraphy described previously in the Phase 4A documentation (GLAL, 1985). The present geologic investigation has produced the following major results:

- better definition of the physical character and distribution of each of the geologic units;
- the examination of shallow depressions on the site; and
- interpretation of depositional conditions of the Halton Unit at the site.

The major Quaternary geologic units are described in detail in the following sections. Section 2.3.6 "Regional Relationships" provides a discussion of the findings of the present study as they relate to the documented studies conducted in the Niagara Peninsula, particularly the regional geologic synthesis undertaken by Feenstra (1981b) and the geologic and geotechnical studies along the Welland Canal realignment (Owen, 1969; 1972)

2.3.2 UPPER GLACIOLACUSTRINE UNIT

The Upper Glaciolacustrine Unit is present at or near surface

throughout the study area (Figures 2-5, 2-6, 2-7). This unit was encountered at all 1984 and 1985 on-site and off-site borehole locations and was encountered (locally beneath a thin covering of sediment on swales) in soil probe holes, auger holes and trenches throughout the site. The unit ranges between 5.1 and 8.2 m in thickness on-site and is slightly thicker (9.1 m) at location 85-16 to the north, off-site.

Texturally, the Upper Glaciolacustrine Unit lies between a clayey silt and a silty clay. Clay content ranges from 25 to 60%, silt from 40 to 65% and sand (with gravel) is less than 10%. Grain size analyses are presented in Appendix E1. The unit is commonly laminated with massive zones and contains occasional silt laminae to several millimetres in thickness. Occasional rock or silt/clay clasts occur throughout most of the unit. Textural variations were noted regionally within the Upper Glaciolacustrine unit in the Phase 4A investigations of sites LF-3C and LF-1E (GLAL, 1985). Minor textural variations were noted during the present investigations at borehole locations 85-7, 85-9 and 85-12.

The Upper Glaciolacustrine Unit is heavily weathered to at least a 1 m depth below surface at most borehole locations. Primary structural features such as laminations are completely obliterated and the general character of the material has been altered by the weathering processes. For example, laminations, silt clasts and silt laminae, which are common in glaciolacustrine sediments, are not recognizable in the weathered zone. Fractures were frequent to approximately 3 m, occasional to 5 or 6 m, and rare or missing beneath 6 m. The deepest observed fracture was encountered in borehole 85-12-1 at 12.1 m. The fractures were generally infilled with a soft

grey, carbonate rich, clay textured material. Rusty and/or black staining along fractures was occasionally encountered. Oxidation zones, where the soil is discoloured, were often present on either side of the fractures to distances of up to 20 mm. Gypsum crystals were occasionally noted in fractures. Most fractures appeared to be infilled beneath approximately 3 m. The depth and frequency of the fractures varied at each drilling location. In general, fracturing was more extensive beneath ridge features and less extensive beneath the swales.

A subtle colour change from typically oxidized and mottled grey browns and yellowish browns to a consistent brown or grey colour with increasing depth was observed in all boreholes. The colour change was generally observed between 3.4 to 6.4 m but most commonly occurred between 4.0 and 4.5 m depth. A summary of weathering features is presented in Table 2-2. The reader should consult Vorauer et al. (1986) for a discussion of the mechanisms of fracture formation.

The surface of the Upper Glaciolacustrine Unit (i.e. the ground surface) exhibits a pattern of poorly drained depressions. These features were described previously in Section 2.2.2.

2.3.3 HALTON UNIT

The Halton Unit, which underlies the Upper Glaciolacustrine Unit, comprises a thick sequence of clayey silt (Figures 2-5, 2-6 and 2-7). This unit was encountered in all deep boreholes. The two shallow boreholes completed at locations 85-17 and 85-18 were finished in the upper few metres of this unit.

TABLE 2-2: SUMMARY OF WEATHERING FEATURES AT BOREHOLE LOCATIONS

BOREHOLE LOCATIONS	DEPTH (METRES)		FRACTURE DEPTHS (METRES)		
	HEAVILY WEATHERED	COLOUR CHANGE	FREQUENT FRACTURES	OTHER OBSERVED FRACTURES	MAXIMUM DEPTH
<u>On-Site</u>					
85-1	0.6	6.4	2.2	3.2 3.6, 3.9, 4.7-6.6*	6.6
85-2	1.0	6.3	1.0	3.3-3.5*	3.5
85-3	1.0	4.5	4.0	5.6*	5.6
85-4	3.0	5.4	3.0	4.0 5.5-7.0*, 9.7*	9.7
85-5		5.6	2.4 heavily		
85-6	1.0	4.0	4.0 2.0	5.3-6.0* 4.8-5.8, 9.0, 6.2*	6.0 9.0
87-7	2.9	4.4	2.9	3.7-8.3*, 9.0*	9.0
85-8		5.3	3.5	8.2-8.5*	8.5
85-9	1.0	4.6	3.0	to 3.0*	3.0
85-10	1.0	3.4	4.0	to 4.0*	4.0
85-11		4.9		5.8-5.9, 5.6* 5.1-5.3*	5.9
85-12	1.0	4.1	5.0	6.4-7.1*, 10.1-12.1*	12.1
85-17		no observed colour change	no observed fractures		
85-18		no observed colour change	no observed fractures		
84-GL-1	1.0	3.4	5.1	to 5.5*	5.5
84-GL-2	1.0	4.1		to 5.5*	5.5
84-GL-3	1.0	5.7	5.1	8.8-10.3	10.3
84-GL-4	1.0	5.7	2.7		2.7
84-GL-5	1.0	5.2	3.3		3.3
<u>Off-Site</u>					
85-13	1.0	5.0	3.0	to 3.0*	3.0
85-14	1.0	4.0	3.0	to 3.0*	3.0
85-15	2.0	6.0	5.0		
85-16	1.0	4.0	4.4		

* infilled and/or gypsum crystals observed

The detailed drilling during the present phase of investigation has revealed that the Halton Unit is not entirely till as inferred from the work of Feenstra (1981b). Rather, it is a sequence of interbedded till (mainly waterlain) and glaciolacustrine sediments. These interpretations are discussed in Section 2.3.6.

The total thickness of till and the thickness of individual till layers within the unit varies both vertically, at the same borehole location, and horizontally, between borehole locations. Textural difference between the till and glaciolacustrine portions of the unit are relatively minor and the contacts are gradational throughout the sequence.

In general, the till portion of the Halton Unit consists of massive to slightly laminated clayey silt with 10% or more rock clasts (sand sized or larger, >0.02 mm). The glaciolacustrine sediments are generally poorly to moderately well laminated, contain significantly fewer rock clasts (to 4%), display a subtle grain size sorting not common to the till, and contain occasional well developed textural laminations or discrete silt laminae. The main till/ glaciolacustrine zones and the presence of silt beds are identified in the borehole logs presented in Appendix C1. A moderate amount of textural variability, aside from clast content, was observed between some zones of the till and glaciolacustrine materials. The till averaged 45 to 50% silt, 35 to 40%, clay and 15 to 20% sand and gravel (Appendix E1). Much of the glaciolacustrine material averaged 65 to 70% silt and 20 to 30% clay with approximately 5% sand. Silt beds and/or intervals of frequent silt laminae were observed in the Halton Unit on the southern edge of the site (85-10, 85-11, 85-12, and 84-1). Two grain size analyses

from the silt indicate approximately 80% silt with nearly equal proportions of sand and clay.

The contact of the Halton Unit with the Lower Glaciolacustrine Unit is either sharp, or it is gradational over a short interval. The contact is readily recognized by the appearance of the colour banding which is a characteristic feature of the two glaciolacustrine units, particularly the lower. The colour banding corresponds with well developed laminations. The Halton Unit typically exhibits a basic brown colour.

The contact of the Halton Unit with the Upper Glaciolacustrine Unit is not always as readily identified. Where the till occurs at the top of the Halton Unit (e.g., locations 85-1, 84-2) the contact is recognizable as a change with depth from well laminated to massive material. Where the upper part of the Halton consists of glaciolacustrine sediment, the contact is often recognized as a change with depth from well laminated to poorly laminated or massive material (e.g. locations 85-5, 85-17). In both cases there is commonly a slight increase in grain size from silt and clay to clayey silt. A decrease in water content is common at the contact (e.g., location 85-5, 85-18).

The Phase 4A borehole logs were reviewed in an effort to redefine the upper and lower contacts of the Halton Unit, particularly in light of the presence of multiple interbedded layers of till and glaciolacustrine sediments. In several cases, the borehole samples stored at the Ontario Geological Survey were re-examined.

In most cases the contacts could be identified from the previous logging notes. The revised Phase 4A borehole logs are

presented in Appendix C1. The basic physical descriptions of the materials was not altered.

Total thicknesses of the Halton Unit range from 12.7 to 16.8 m. A slightly larger range was observed in the off-site boreholes (11.8 to 18.5 m). Both the thicknesses and the elevations of the upper and lower contacts vary little over the site. Thicknesses of the Halton Unit noted by Owen (1972) in the Welland-Port Colborne area were slightly less (approximately 10 m thickness). Feenstra (1981b) records substantially greater maximum thicknesses of Halton sediments (to 43 m) within bedrock depressions within the Twelve Mile Creek valley. The overall values of thicknesses and elevations at the Preferred Site are similar to the regional values presented in Feenstra (1981b).

The proportion of till within the Halton Unit averages about 35% but ranges from 90% or more (85-2 and 85-3) to 0% (85-8, 85-11 and 85-12). In general there is a larger proportion of till toward the north end of the site. Up to five well defined subunits of till were encountered at the Preferred Site, although one to three subunits were more common at most locations. Many of the till/glaciolacustrine contacts are gradational and in some areas the two are interbedded (e.g., location 85-9).

Fractures were observed in the upper portion of the Halton Unit in many of the on-site boreholes. One fracture was observed to extend to a maximum depth of 12.1 m (85-12) or 4.6 m into the Halton Unit. Fractures were typically infilled with a grey, carbonate rich, clayey material (occasionally stained black). The fractures were sometimes highlighted by a rusty or brown oxidized zone or halo and occasionally contained gypsum crystals and plant roots.

The significance of this information to the regional historic and stratigraphic framework is discussed in Section 2.3.6.

2.3.4 LOWER GLACIOLACUSTRINE UNIT

The Lower Glaciolacustrine Unit was encountered in all deep boreholes completed during the 1985 and 1984 programs (Figures 2-5, 2-6 and 2-7). With collection of additional data (1985 program) the upper geologic contact for this unit was re-evaluated and the position modified (Appendix C1). This unit is generally 10 to 11 m thick but ranges from 7.8 m (85-4) to 14.6 m (85-3).

The Lower Glaciolacustrine Unit is composed of approximately equal proportions of silt and clay with minor amounts (to 5%) of disseminated sand particles. The unit is generally well laminated with characteristic red and grey colour banding on a brown background. The colour banding is attributed to slight increases and decreases in the clay content of the material. Silt laminae to 2 or 3 mm in thickness are common in portions of the unit and silt and clay clasts were occasionally noted. The unit is generally consistent and uniform in both its general appearance and physical character.

Feenstra (1981b, p. 83) has noted four facies of the unit:

- (1) a basal silt and fine sand;
- (2) a lower laminated silt and clay;
- (3) a massive till-like silt and clay; and
- (4) an upper laminated silt and clay.

Although it is possible to identify sediments which likely correspond to each of these facies, the bulk of the material

at most borehole locations is laminated silt and clay. A probable "basal sub-unit of silt and fine grained sand..." (Feenstra, 1981b, p.83) was identified at borehole location 85-1. A middle till-like unit was identifiable at borehole locations 85-8 and 84-3. Thinner and less well developed till-like zones were also occasionally observed elsewhere.

The upper contact of the Lower Glaciolacustrine Unit is either distinctive, or it is gradational over a short interval. The contact is marked by the beginning of colourful banding, laminations and a greater clay content than the overlying Halton Unit. The contact with the Lower Till is marked by an abrupt change in grain size and density. Some minor mixing was observed at the contact, notably at borehole locations 85-10 and 85-11.

2.3.5 LOWER TILL

The Lower Till was encountered at all deep boreholes completed during the 1985 and 1984 programs (Figures 2-5, 2-6, 2-7). On-site, the Lower Till ranges from slightly less than 1 m in thickness (84-2) to a maximum of more than 5 m in thickness (85-10). At off-site borehole location 85-14 the unit is more than 10 m thick. The thickness of Lower Till at this location was initially noted as a geophysical anomaly and drilled for confirmation (Appendix D).

Grain size analyses for Lower Till samples (Appendix E1) indicate approximately equal proportions of gravel, sand and silt with commonly 5 to 10% clay. Many of the borehole samples contained increasing gravel content with proximity to bedrock (ranging from approximately 20% to more than 40%). Sand inclusions were noted at five borehole locations (85-3, 85-9, 85-11,

84-3 and 84-5). A transitional clay-rich zone between the Lower Till and the overlying Lower Glaciolacustrine Unit was noted at two locations (85-5, and 85-10). Both upper and lower contacts are easily identified in spite of a certain amount of mixing of these units.

The borehole and geophysical data indicate that the Lower Till is a consistent blanket of sediment overlying the bedrock surface on the site. One thicker anomaly (to 10 m) was encountered approximately 1 km south of the site at borehole location 85-14.

Thicker areas of the Lower Till have been noted in the Welland Canal excavations (Owen 1972) and are well known in the drumlins of the Caledonia Drumlin Field approximately 10 km to the southwest of the study area. The potential presence of large scale increases in the thickness of the Lower Till over the site has been eliminated. The borehole information and accompanying geophysical profiling across the site (Appendix D) confirms only minor thickness variations.

2.3.6 REGIONAL RELATIONSHIPS

Some academic issues which relate to the geology and geologic history of the Preferred Site are addressed in this section. This discussion has been separated from the foregoing passages because it focusses on issues which are peripheral to the immediate site area.

The Upper Glaciolacustrine Unit is recognized throughout the Niagara Peninsula. This unit is consistent in thickness over the site. There is no evidence of thinning which might relate to a bedrock high or a moraine. Sand lenses have been

recorded in this unit at sites LF-3C and LF-1E but were not observed at the Preferred Site.

The Halton Till and its various vertical and lateral facies are described in detail by Feenstra (1981b). Feenstra's analysis does not, however, make reference to the materials in the vicinity of the Preferred Site as data from the West Lincoln area (i.e. borehole logs) were not available at the time Feenstra's work was undertaken.

The Halton Unit, as defined in Section 2.3.2, refers to the sequence of interbedded till and glaciolacustrine sediments (referred to as Halton sediments) which underlie the Upper Glaciolacustrine Unit (Table 2-1). This sequence of sediments was referred to by Feenstra (1981b) as the Halton Till.

During the initial (Phase 4A) investigation of the site, the formal name Halton Till was adopted to identify the "till" portion of the sequence. The detailed Phase 4B investigation resulted in the present recognition of the full thickness and composition of the Halton sediments.

The name Halton Unit is used in this study, rather than the formal name Halton Till, in recognition of the dominantly glaciolacustrine origin of the Halton sediments in the vicinity of the Preferred Site. Although till is present, the till constitutes a minority component of the sequence and much of the "till" is either waterlain or shows the influence of standing water. The general thickness and attitude of the Halton Unit in the present interpretation are very similar to the detailed stratigraphic exposures along the Welland Canal realignment (Owen, 1969; 1972).

The close association of Halton Till with glaciolacustrine sediments was noted by Feenstra (1981b). The Halton Till was demonstrated by Feenstra to have overridden and incorporated fine-grained, glaciolacustrine materials (the Lower Glaciolacustrine Unit). Feenstra also notes several locations of intercalated Halton Till and glaciolacustrine sediments. There is a large body of evidence to demonstrate the existence of a lake in front of the Halton ice and there is also evidence to suggest that a lake environment existed beneath parts of the ice at times during its history. Many of these occurrences noted by Feenstra are associated with either ice-frontal positions (i.e. moraines) or areas of bedrock lows. Evidence which suggests that the Halton ice must have been at least partially floating during deposition of the Halton Unit in the study area includes:

- the general dominance of waterlain sediment in the Halton Unit;
- the lack of major disturbance or thrust features suggestive of a grounded ice mass;
- the presence of a large bedrock depression beneath the study area; and
- the observation that the Lower Glaciolacustrine Unit is only slightly over-consolidated (suggesting that it has not been subjected to the substantial weight of an overriding ice sheet).

The presence of a floating body of ice in the area during the deposition of the Halton Unit may also be responsible for

absence of the Fort Erie, Crystal Beach, Mohawk Bay and Wainfleet Moraines in the Wainfleet-Caistor Corners-Smithville area. These features which have not been detected either at surface or in the subsurface within this area of deeply buried bedrock, may never have been deposited in the area. The occurrence elsewhere of these features appears to be limited to areas of shallow bedrock such as along the Onondaga Escarpment or keyed to major glacial features such as the Fonthill ice-marginal feature.

A deep borehole located approximately 2 km southeast of Wainfleet is known to have penetrated the entire Upper Glaciolacustrine, Halton and Lower Glaciolacustrine sequence (Desaulniers, 1980). Approximately 3 m of Halton Till is recorded in the log for this borehole between a depth of approximately 10 and 13 m. The geologic interpretation is consistent with the 1984 interpretations of the stratigraphy at the Preferred Site (GLAL, 1985). It is possible a more detailed borehole program at the Wainfleet location may have confirmed the presence of a sequence of till and glaciolacustrine sediments similar to that encountered at the Preferred Site.

The Lower Glaciolacustrine Unit was identified in deep excavations such as the Welland Canal and in deep boreholes elsewhere in the Niagara Peninsula. The unit is inferred to be present throughout the thicker drift areas of the Niagara Peninsula but commonly missing where bedrock is closer to surface. The unit at the Preferred Site is very similar in character and thickness to sediments noted by Owen (1969; 1972) and by Feenstra (1981b).

A basal till unit, which corresponds to the Lower Till identified in this study, has been noted at scattered locations throughout the Niagara Peninsula (Feenstra, 1981b). It is closely associated with the underlying bedrock and consequently exhibits a significant amount of physical variability from place to place. Barnett (1975) based on an examination of available exposures and samples of this till, concluded that the basal till unit present in the Niagara Peninsula correlates with the Wentworth Till of the Hamilton area. The Lower Till encountered in boreholes at the Preferred Site exhibited some textural variability between boreholes. It also exhibited a high proportion of dolomite in the matrix and an abundance of dolostone clasts. The dominance of dolomite is reasonable in view of the presence of the Guelph Formation dolostone beneath the site and for many kilometres in an up-ice direction (north). Values obtained were similar to those reported by Feenstra (1981b, p.77) for a "Lockport Formation derived local till" which also overlies a dolostone bedrock.

In summary, the stratigraphy at the Preferred Site is in close agreement with the interpretation presented in published studies of the regional geology. The addition of detailed information from the present study has significantly improved the level of detail.

2.4 BEDROCK GEOLOGY

The bedrock beneath the Preferred Site was identified as the Guelph Formation dolostone in previous studies (GLAL 1984a; 1985). It is the uppermost of a thick series of sedimentary rocks underlying the site (Figure 2-4). The bedrock units dip gently to the south at approximately 5.5 to 8.5 m/km (Winder and Sandford, 1972).

The Guelph Formation was encountered in all Phase 4A and Phase 4B boreholes penetrating to bedrock. The Guelph Formation is grey, finely crystalline, sugary-textured dolostone with occasional shale laminae and vugs. In general, the upper metre or two of rock encountered in each borehole was fractured. Fractures decreased in frequency below this depth and generally occurred only along shale laminae. Many of the laminae, fractures and vugs contain gypsum. The rock was of similar character at all borehole locations and descriptions are similar to those presented by Telford et al. (1976), Winder and Sanford (1972) and Bolton (1957).

Telford et al. (1976) inferred the presence of the overlying Salina Formation in close proximity to the south edge of the study area (Figure 2.8). The Salina Formation is comprised of dolostone, shale and evaporites. The evaporite minerals present in these rocks are known to affect the ground water quality where they occur.

Boreholes 85-1-12 (northwest corner) and 85-12-12 (south-east corner) were extended 30.9 m and 34.3 m respectively into rock. Both boreholes appear to have penetrated the Guelph Formation dolostone and have entered the underlying Eramosa Member of the Lockport Formation.

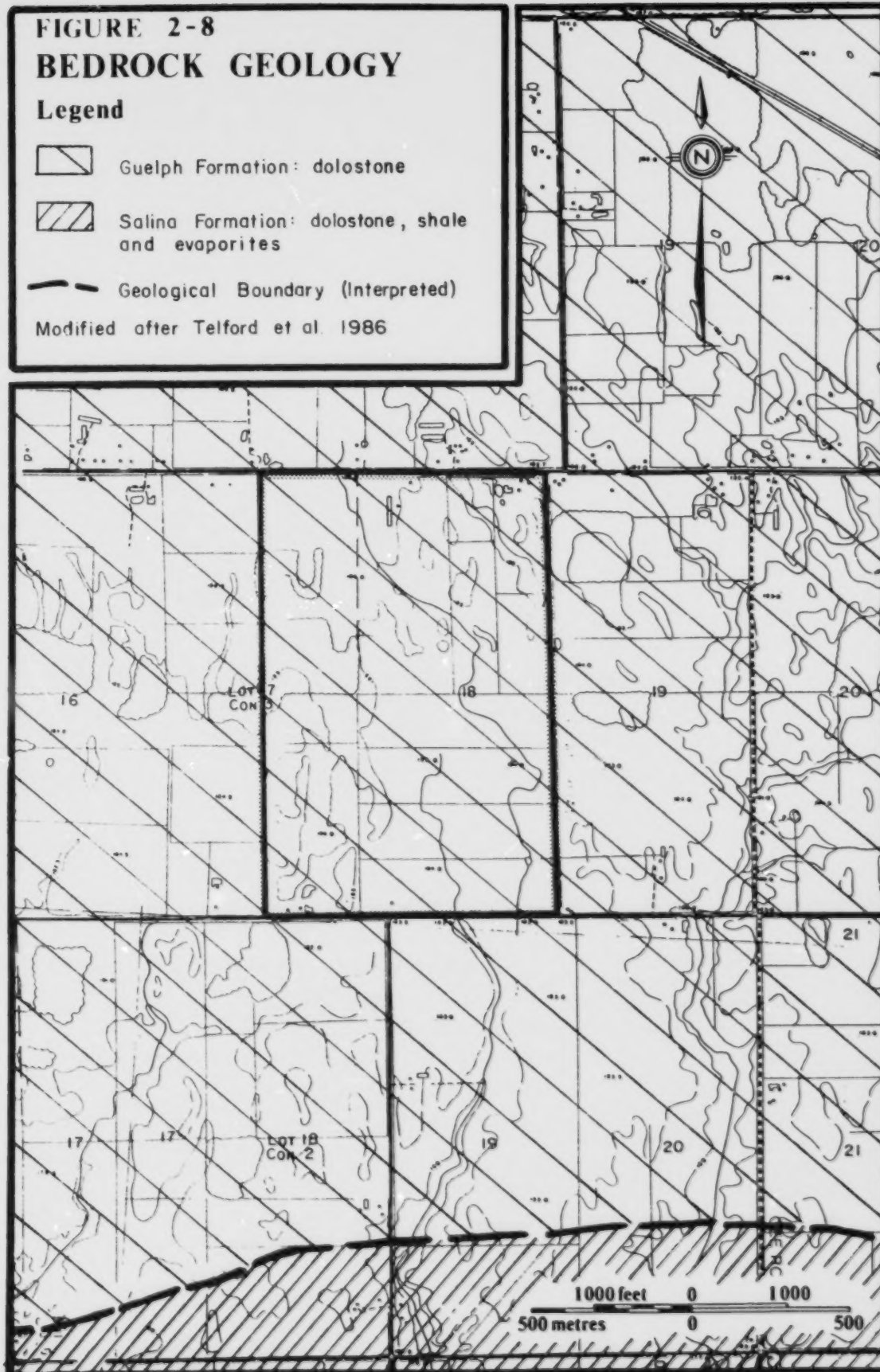
The contact between the Guelph Formation and the Eramosa Member of the Lockport Formation is generally considered to be gradational and subtle (Winder and Sanford, 1972; Bolton, 1957). The two bedrock units are recognized as being conformable and, in at least one location, are interbedded (Winder and Sanford, 1972, p. 61). Data on the position of the Guelph-Eramosa contact in the Niagara Peninsula are sparse. The

FIGURE 2-8 BEDROCK GEOLOGY

Legend

-  Guelph Formation: dolostone
-  Salina Formation: dolostone, shale and evaporites
-  Geological Boundary (Interpreted)

Modified after Telford et al. 1986



presence of petroliferous odour, a slight colour change, the presence of chert nodules, an increase in the number of vugs and shale laminae, a slight decrease in grain size and the presence of observable fossils combine to suggest that the Guelph-Eramosa contact was encountered at borehole locations 85-1 and 85-12. The contact is tentatively placed at 127.7 m.a.s.l. in borehole 85-1-12 and at 120.6 m.a.s.l. in borehole 85-12-12. The resulting thickness of the Guelph Formation below the Preferred Site is 23.5 and 25.4 m, respectively at these two borehole locations.

2.5 BEDROCK TOPOGRAPHY AND OVERBURDEN THICKNESS

The regional bedrock topography has been assessed by Feenstra (1981a) and more recently by Flint and Lolcama (1986). Both these studies indicate that the bedrock slopes gently to the south-southeast beneath the site. The bedrock topography is presented in Figure 2-9. Bedrock elevations were determined from the 1984 and 1985 boreholes and from water well information. The trend of the bedrock surface between data points is confirmed by geophysical profiling (Appendix D).

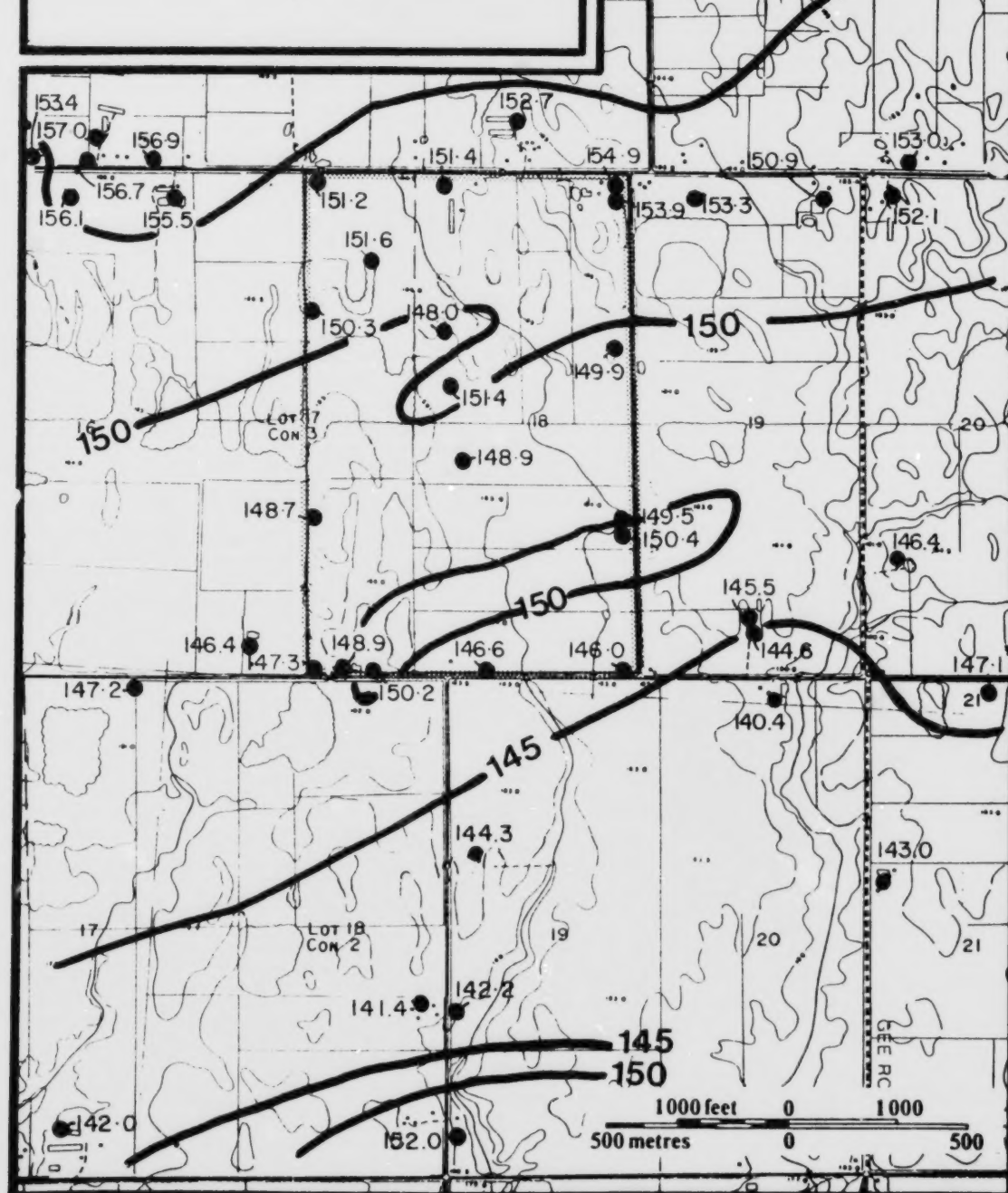
The bedrock topography depicted in Figure 2-9 confirms the regional pattern. The bedrock slopes from approximately 155 m a.s.l. at the northeast corner of the site to 146 m a.s.l. at the southeast corner. Locally, the bedrock relief is on the order of several metres. A slight ridge may exist below the southern portion of the site as indicated by the closed 150 m contour. A small north-facing scarp may be present approximately one km south of the site as interpreted from the closely spaced contours in this area. This scarp appears to coincide with the approximate position of the boundary between the Guelph and Salina formations (Figure 2-8).

FIGURE 2-9 BEDROCK TOPOGRAPHY

Legend

● 158.3 Water Well Or Borehole Location With
Bedrock Elevation In Metres

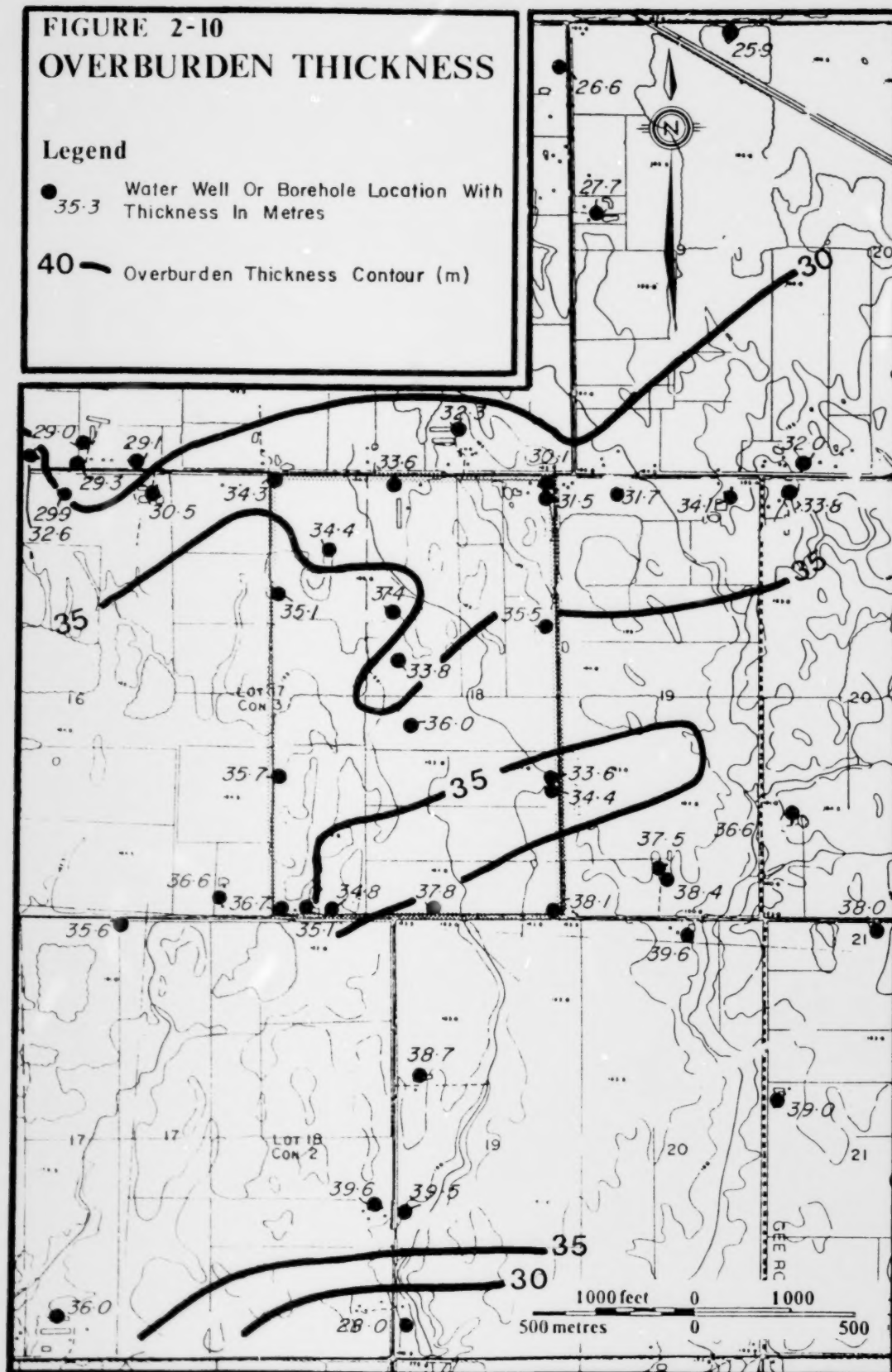
— 155 Bedrock Topography Contour (m)



Overburden thickness interpretation (Figure 2-10) is based on the same borehole, water well and geophysical data that provide the basis for the bedrock topography interpretations. On-site overburden thicknesses increase in a south-southeasterly direction from approximately 30 m in the north to 38 m at the southeast corner of the site. The overburden thins to about 34 m over the slight bedrock ridge present near the southern edge of the site. The overburden thickness decreases to approximately 27 m one km north of the site. Immediately south of the site, the overburden thickness increases to about 39 m. Further south the overburden thins, to about 28 m in the vicinity of the bedrock scarp.

Legend

40 — Overburden Thickness Contour (m)



3-1

3.0 PHYSICAL HYDROGEOLOGY



PHYSICAL HYDROGEOLOGY
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3.0 PHYSICAL HYDROGEOLOGY

3.1 INTRODUCTION

3.1.1 PURPOSE AND SCOPE

The hydrostratigraphy, hydrogeologic properties of the major hydrogeologic units, and the local and regional ground water flow system at OWMC's Preferred Site, are described in this section.

During Phase 4A, information on the physical hydrogeology of the Preferred Site was inferred from on-site geologic conditions established from completion of five on-site boreholes, water well records and from existing published studies. The boreholes completed during Phase 4A were not instrumented and no testing for hydrogeologic parameters was undertaken. The Phase 4B geoscience program supplements this existing data base with the results of detailed field and laboratory testing. A summary of the field and laboratory testing component is presented in Section 3.1.3.

The structure of the remainder of Section 3.0 is as follows. Section 3.2 identifies the major hydrostratigraphic units and details the hydrogeologic properties of each of these units. Section 3.3 describes ground water flow at the Preferred Site in a regional and local context.

3.1.2 BACKGROUND

Previous descriptions of the physical hydrogeology of the Preferred Site study area, provided in the Phase 3B and Phase 4A studies (GLAL, 1984b, 1985), were based primarily on an

understanding of geologic/hydrogeologic interrelationships. Additional information is available from studies conducted elsewhere in the Niagara Peninsula where the hydrogeologic setting is relatively similar. These include a hydrogeologic research project in Wainfleet Township (Desaulniers et al, 1981), and hydrogeologic studies related to the Welland Canal realignment (Conlon et al., 1971; Christensen and Nisbet, 1973; Farvolden and Nunan, 1970).

3.1.3 METHODOLOGY

In addition to the sources of information referenced in Section 3.1.2, additional hydrogeologic data was collected during the OWMC Phase 4B geoscience program. Major sources of data include the field study component which involved drilling and hydrogeologic testing, laboratory testing, water well records and water use survey results, and theoretical analysis.

In establishing ground water flow directions, velocity and quantities it was necessary to collect specific information on the hydrogeologic properties of the various geologic units and on the distribution of hydraulic head in these units. Specific information requirements include:

- thickness of the geologic/hydrostratigraphic units;
- porosity and hydraulic conductivity; and
- hydraulic head.

Thicknesses of the various geologic hydrostratigraphic units have been established by the stratigraphic logging and geophysics programs (Section 2.0). Matrix porosity values for the weathered and unweathered silt and clay were determined during laboratory testing as part of the geotechnical

program (Section 6.0). Porosity values for the Lower Till were estimated using water content measurements (Section 3.2.2). Hydraulic conductivity values were obtained using a variety of field and laboratory testing techniques. The protocols, results and analysis of these tests are presented in detail in the appendices cited below. The various testing techniques used to collect the hydraulic conductivity information included:

- water level recovery in monitors following installation in dry holes (details provided in Appendices A4, F2, G1);
- slug testing (Appendices A3.2, G2);
- packer testing (Appendices A3.3, G3);
- pump testing (Appendices A3.4, G4); and
- laboratory testing (Appendices A3.5, G5).

Hydraulic heads were established by water level measurements in standpipes, piezometers and pneumatic piezometers installed during the field program. The methods used in collection of this information are described in Appendix A3.1.

3.2 HYDROSTRATIGRAPHY AND HYDROGEOLOGIC PROPERTIES

3.2.1 INTRODUCTION

Hydrostratigraphic units are sequences of geologic materials that possess similar hydrogeologic properties including hydraulic conductivity and porosity. A hydrostratigraphic unit may be comprised of a portion of a geologic unit, an entire geologic unit, or several geologic units. The hydrostratigraphy of the Preferred Site was derived from a detailed assessment of the hydrogeologic properties of each of the geologic units described previously in Section 2.0.

The hydrostratigraphic units that have been identified in this report are illustrated in Table 3-1. Also included is their relationship to the geologic units at the site, and the corresponding Phase 4A hydrostratigraphic terminology.

The hydrostratigraphic units have been divided into two major groups, identified as the Aquitard and the Bedrock Aquifer. These groupings are convenient for discussion purposes as they correspond to the two principal geologic groupings, namely the overburden and the bedrock.

The Aquitard is composed of three hydrostratigraphic units:

- (1) weathered silt and clay;
- (2) unweathered silt and clay; and,
- (3) Lower Till.

The hydrogeologic properties of each of these units are presented in Section 3.2.2.

The Bedrock Aquifer consists of two geologic units to the depths tested at the site; namely the Guelph Formation dolostone and the Lockport Formation dolostone. However, varying hydraulic conductivities within the bedrock allowed for the definition of five hydrostratigraphic units, termed Zone A to Zone E. The hydrogeologic properties of each of these units are presented in Section 3.2.3.

3.2.2 AQUITARD

The hydrogeologic properties of the three hydrostratigraphic units of the Aquitard are described below.

TABLE 3-1: HYDROSTRATIGRAPHY RELATIVE TO GEOLOGIC UNITS

PHASE 4A HYDROSTRATIGRAPHY UNITS	GEOLOGY UNITS	PHASE 4B HYDROSTRATIGRAPHY	
		GROUP	UNIT
CONFINING LAYER	UPPER GLACIOLACUSTRINE	AQUITARD	WEATHERED SILT AND CLAY
	HALTON UNIT		UNWEATHERED SILT AND CLAY
	LOWER GLACIOLACUSTRINE UNIT		
	LOWER TILL		LOWER TILL
BASAL GRANULAR* AND BEDROCK AQUIFER	BEDROCK-GUELPH AND LOCKPORT FORMATIONS	BEDROCK AQUIFER	ZONE A
			ZONE B TO ZONE E

*BASAL GRANULAR NOTED IN PHASE 4A REGIONAL GEOLOGY NOT FOUND AT THE PREFERRED SITE.

3.2.2.1 Weathered silt and clay

As noted in the geologic description (Section 2.3.2), the upper few metres of the Upper Glaciolacustrine Unit are extensively weathered and contain numerous interconnected fractures. Ground water movement through the weathered zone is primarily through the fractures. The thickness of the weathered silt and clay is not sharply defined, as the extent of weathering and frequency of fractures decreases gradually with depth. The base of this unit will not necessarily coincide with the depth of the deepest fracture, as many of the deep fractures are considered to be hydrogeologically isolated and consequently will not transmit water any more rapidly than the matrix. Based on the observation of fractures in boreholes and in shallow trenches, the weathered silt and clay is assumed to be about 5 metres in thickness, extending down from ground surface. The hydrogeologically active portion of this unit is expected to be the upper 2 to 3 m.

The weathered silt and clay unit is a dual porosity medium. The fracture porosity (which results from consideration of only the fractures) is generally very small relative to the intergranular porosity of the unfractured soil matrix. Because the fractures are volumetrically small, the bulk porosity of the unit tends to be very similar to the matrix porosity. Laboratory testing for two soil samples conducted as part of the geotechnical program (Section 6.0) yielded porosity values of 0.38 and 0.48 for the weathered silt and clay. These values are considered to be representative of the matrix porosity because of the similarity with the porosity values of the underlying unweathered silt and clay. Fracture porosity can vary widely depending on the character of the fractures, namely their aperture, infilling, orientation, and interconnection.

Fracture porosity would be expected to change with depth as the character of the fractures change.

Table 3-2 presents published values for porosity and hydraulic conductivity for fractured and unfractured silt and clay materials. Typically, fracture porosity values are much lower than those for matrix porosity. The fracture porosity of the weathered silt and clay was not established for the OWMC site but rather has been estimated to be about $1\text{E-}4$ based on the information presented in Table 3-2. Should a more precise fracture porosity value be required for future studies, it may be necessary to conduct detailed field tracer tests combined with theoretical analysis.

Table 3.3 presents values of hydraulic conductivity determined by slug and laboratory testing. The slug test values have a range of $2\text{E-}9$ m/s to $7\text{E-}7$ m/s, with a geometric mean of $2\text{E-}8$ m/s. The wide range is typical of fractured formations since the frequency, orientation, aperture, interconnection and infilling of the fractures encountered by each monitor will vary. The fractured hydraulic conductivity values shown in Table 3-2 also demonstrate a great deal of variability.

The slug tests identified in Table 3-3 were performed in standpipes that were slotted over a 4 m interval starting about 1 m below ground surface. These tests result in a bulk hydraulic conductivity that is probably most representative of the hydraulic conductivity at the water elevation at the time of testing, typically 1 m to 2 m below surface. Below this depth, the hydraulic conductivity decreases as the fractures become tighter and less frequent. It is expected, then, that in general the hydraulic conductivity in the weathered silt and

**TABLE 3-2: SUMMARY OF PUBLISHED POROSITY AND HYDRAULIC CONDUCTIVITY
VALUES FOR FRACTURED AND UNFRACTURED SILT AND CLAY**

SOURCE	LOCATION	POROSITY		HYDRAULIC CONDUCTIVITY m/s	
		FRACTURED	UNFRACTURED	FRACTURED	UNFRACTURED
Desaulniers et al (1982)	Bruce County, Ontario			1E-6 to 1E-5	2.1E-10 to 2.2E-10
Desaulniers et al (1982)	Lambton County, Ontario	1E-4	0.43	1E-10 to 5E-10	5.4E-11 to 1.48E-9
Desaulniers (1980)	Sarnia, Ontario		0.29-0.41		8.3E-11 to 7.5E-10
	Wainfleet, Ontario		0.34-0.60		1.1E-10 to 8.2E-10
	Woodslee, Ontario		0.31-0.37		2.4E-11 to 9.3E-10
	Wyoming, Ontario		0.22-0.38		5.0E-11 to 7.3E-10
Goodall and Quigley (1977)	Sarnia, Ontario		0.3		1.2E-10 to 1.7E-8
Conlon et al (1971)	Welland, Ontario				2E-10 to 4E-10

TABLE 3-3: VALUES OF HYDRAULIC CONDUCTIVITY
WEATHERED SILT AND CLAY

BOREHOLE	ELEVATION TESTED (mASL)	HYDRAULIC CONDUCTIVITY (m/s)	
		SLUG TEST	LABORATORY
85-2-5	182.21 - 179.21	6E-9	
85-4-5	183.71 - 179.82	4E-9	
85-5-5	183.88 - 179.88	7E-7	
85-7-5	182.80 - 178.80	2E-9	
85-8-5	183.48 - 179.48	4E-9	
85-9-5	182.37 - 178.37	5E-9	
85-10-5	182.50 - 178.50	5E-7	
85-11-5	182.75 - 178.86	6E-9	
85-12-5	182.36 - 178.47	1E-8	
85-13-2	183.65 - 179.65	2E-7	
85-14-2	180.13 - 176.13	1E-8	
85-15-2	181.11 - 177.11	4E-8	
85-16-2	184.29 - 180.29	5E-7	
85-5-2	181.16 - 180.55		6E-10
85-1-8 V	181.02		2E-10
85-1-8 H	181.22		2E-10
85-8-8 V	180.89		8E-11
85-8-8 H	180.99		2E-10
85-12-8 V	180.20		4E-10
85-12-8 H	180.28		2E-10

NOTE: " V " or " H " represents vertical or horizontal
orientation in laboratory test

clay decreases with increasing depth in proportion to the observed decrease in fracture frequency and aperture. The published values shown in Table 3-2 also show that fractured hydraulic conductivity is generally greater than unfractured hydraulic conductivity.

Laboratory tests were performed on small samples and therefore are considered to represent the hydraulic conductivity of the silt and clay matrix, exclusive of the fractures. Three samples were tested, each in both horizontal and vertical orientations. No significant anisotropy was noted. The values ranged between $8\text{E-}11$ m/s and $6\text{E-}10$ m/s with a geometric mean of $2\text{E-}10$ m/s (Table 3-3). These values are consistent with the hydraulic conductivity values determined for the underlying unweathered silt and clay. This confirms that the hydraulic conductivity values are representative of the silt and clay matrix rather than the fractures, and that the hydraulic conductivity of the silt and clay matrix is consistent through both the fractured and unfractured units.

3.2.2.2 Unweathered silt and clay

The unweathered silt and clay portion of the Aquitard extends from the base of the weathered silt and clay to depths ranging between 29.9 m and 35.3 m, averaging about 32.7 m below ground surface. Assuming the weathered silt and clay to be about 5 m thick, the unweathered silt and clay thickness would range between 25 m and 30 m, averaging about 28 m.

The bulk porosity of this unit, as determined by geotechnical testing, ranges between 0.33 and 0.47, with an average of 0.41. These values are comparable to those determined for other sites in the vicinity of the Preferred Site as shown in Table 3-2.

Table 3-4 presents hydraulic conductivity values for the unweathered silt and clay as determined by recovery analysis, slug testing and laboratory testing. Apart from one exception discussed below, hydraulic conductivity values of the unweathered silt and clay, from all types of testing, ranged between $5\text{E-}11$ m/s to $1\text{E-}9$ m/s, with a geometric mean of $2\text{E-}10$ m/s. No significant variability was noted between horizontal and vertical orientations in laboratory testing, therefore the unit is considered to be isotropic. These hydraulic conductivity values for the unweathered silt and clay are similar to those reported at other study sites in the vicinity as shown in Table 3-2.

Slightly higher values of hydraulic conductivity were observed throughout the site in the upper portion of the unweathered silt and clay. Hydraulic conductivities determined from slug tests conducted at 8 m to 10 m depth from surface (boreholes 85-1-11, 85-3-11, 85-8-11, 85-10-11, 85-12-11 in Table 3-4) ranged from $2\text{E-}10$ m/s to $2\text{E-}9$ m/s, with a geometric mean of $8\text{E-}10$ m/s. This may be attributed to the presence of a transition zone between the weathered and unweathered silt and clay. Laboratory testing on small samples at this same depth yielded hydraulic conductivities typical of the silt and clay matrix; a similar relationship as was observed in the weathered silt and clay unit (see previous section).

TABLE 3-4: VALUES OF HYDRAULIC CONDUCTIVITY
UNWEATHERED SILT AND CLAY

BOREHOLE	ELEVATION TESTED (mASL)	HYDRAULIC CONDUCTIVITY (m/s)		
		RECOVERY	SLUG TEST	LABORATORY
85-1-11	176.56 - 175.52		5E-10	
85-3-11	176.73 - 175.73		2E-9	
85-8-11	176.48 - 175.48		1E-9	
85-10-11	175.48 - 174.48		2E-10	
85-12-11	175.44 - 174.54		2E-9	
85-1-4	170.04 - 169.04	1E-10	1E-10	
85-2-4	169.53 - 168.43	9E-11		
85-3-4	170.14 - 169.22	8E-11	2E-10	
85-4-4	170.18 - 169.28	1E-10	2E-10	
85-5-4	168.56 - 167.56	1E-10	1E-10	
85-6-4	170.09 - 169.09	8E-11		
85-7-4	169.10 - 168.10	2E-10	1E-10	
85-8-4	169.72 - 168.72	1E-10	1E-10	
85-9-4	168.65 - 167.65	1E-10	1E-10	
85-10-4	168.79 - 167.79	1E-10		
85-11-4	167.57 - 166.65	1E-10	3E-10	
85-12-4	167.23 - 166.33	2E-10	3E-10	
85-1-3	159.41 - 158.41	1E-10	8E-11	
85-2-3	159.24 - 158.04	1E-10	4E-10	
85-3-3	159.42 - 158.50	2E-10	4E-10	
85-4-3	159.48 - 158.58	2E-10	1E-10	
85-5-3	159.60 - 158.60	2E-10	2E-10	
85-6-3	159.26 - 158.26	1E-10		
85-7-3	158.48 - 157.48	2E-10	8E-11	
85-8-3	158.05 - 157.05	1E-10	1E-10	
85-9-3	158.00 - 157.00	2E-10	2E-10	
85-10-3	158.04 - 157.04	2E-10	2E-10	
85-11-3	156.97 - 156.06	2E-10	3E-10	
85-12-3	158.28 - 157.38	2E-10	2E-10	
85-5-2	163.65 - 163.04			3E-10
85-5-2	160.60 - 159.99			2E-10
85-5-2	156.03 - 155.42			1E-9
85-1-2 V	175.47			1E-10
85-1-2 H	175.75			2E-10
85-1-2 V	169.85			5E-11
85-1-2 H	169.82			6E-11

continued...

TABLE 3-4: continued.....

BOREHOLE	ELEVATION TESTED (mASL)	HYDRAULIC CONDUCTIVITY (m/s)		
		RECOVERY	SLUG TEST	LABORATORY
85-3-2 V	166.77			2E-10
85-3-2 H	167.07			2E-10
85-12-8 V	172.64			5E-10
85-12-8 H	172.81			2E-10
85-12-22V	168.74			3E-10
85-12-22H	168.79			4E-10
85-12-8 V	162.05			2E-10
85-12-8 H	162.05			3E-10
85-5-2	177.36 - 176.75			5E-10
85-5-2	169.74 - 169.13			3E-10
85-1-2 V	160.25			1E-10
85-1-2 H	160.35			1E-10
85-3-2 V	159.14			2E-10
85-3-2 H	159.14			2E-10
85-8-8 V	162.56			2E-10
85-8-8 H	162.66			2E-10
85-10-2 V	158.65			3E-10
85-10-2 H	158.90			3E-10
85-12-22V	155.62			1E-10
85-12-22H	155.77			3E-10
SILT LAYER				
85-10-12	169.04 - 168.04		2E-9	
85-10-2 V	167.77			9E-9
85-10-2 H	167.79			1E-8

NOTE: " V " or " H " represents vertical or horizontal orientation in laboratory test

One exception to the consistent hydraulic conductivity values in the unweathered silt and clay occurred at drilling location 85-10, in the southwest corner of the site. Slug testing in borehole 85-10-12 at about 15 m depth yielded a hydraulic conductivity of $2\text{E-}9$ m/s, which is slightly higher than the surrounding silt and clay. This monitor was installed in a 1 m thick silt layer. The silt layer is discontinuous as it was not encountered in all the boreholes completed at this location or elsewhere on the site. Laboratory tests on samples from the same silt layer (borehole 85-10-2) yielded vertical and horizontal hydraulic conductivities of $9\text{E-}9$ m/s and $1\text{E-}8$ m/s, respectively. No other significant silt layers were found on site.

3.2.2.3 Lower Till

The Lower Till which underlies the unweathered silt and clay, is a relatively thin unit, ranging in thickness between 1.3 m and 5.2 m, and averages about 2.8 m thick. This unit exhibits some stratigraphic variability at the Preferred Site and this is reflected in its hydrogeologic properties.

Porosity was calculated as 0.16 for the Lower Till based on an average water content of 7% and a specific gravity of 2.67, using equations outlined by Craig (1978, p. 15-16). Terzaghi and Peck (1967) list the porosity of a typical mixed-grained glacial till as 0.20.

The hydraulic conductivity values for the Lower Till obtained by slug testing and recovery analysis, are provided in Table 3-5. The values are highly variable, ranging from

TABLE 3-5: VALUES OF HYDRAULIC CONDUCTIVITY
LOWER TILL

BOREHOLE	ELEVATION TESTED (mASL)	HYDRAULIC CONDUCTIVITY (m/s)	
		RECOVERY	SLUG TEST
85-1-2	153.34 - 152.34		2E-8
85-2-2	153.23 - 152.23		6E-10
85-5-2	150.99 - 149.99		2E-9
85-6-2	151.92 - 150.92		>4E-5
85-7-2	150.49 - 149.49	4E-10	7E-10
85-8-2	152.92 - 151.72	3E-10	7E-10
85-9-2	151.29 - 150.29		>7E-5
85-10-2	151.83 - 150.83		7E-10
85-11-2	150.34 - 149.42		4E-8
85-12-2	148.68 - 147.68		7E-10

NOTE: " > " indicates estimated minimum value

3E-10 m/s to greater than 7E-5 m/s (the upper limit of the testing technique). The geometric mean hydraulic conductivity of 2E-8 m/s was used for ground water flow calculations. No pattern was evident to suggest areal zones of higher or lower hydraulic conductivity. Higher values likely indicate hydraulic connection during slug testing to the more permeable bedrock that underlies the Lower Till. This connection may result where the bottom of the monitors are installed very close to the bedrock surface or at some locations by flow through sand and gravel layers noted in the Lower Till.

3.2.3 BEDROCK AQUIFER

The bedrock underlying the Preferred Site was encountered at depths ranging between 31.5 m and 38.1 m below ground surface. The average depth was about 35.5 m below ground surface. The upper few metres of the bedrock at the Preferred Site is extensively fractured. It is assumed that the fractures are related to weathering prior to sediment deposition and have likely been widened by solution. Both vertical and horizontal fracture sets have been noted regionally (Farvolden and Nunan, 1970; Christensen and Nisbet, 1973).

The matrix porosity of dolostone bedrock can vary widely, from less than 0.01 to more than 0.10 depending on its composition and stress history (Goodman, 1980; Freeze and Cherry, 1979). In addition, the presence of fractures imparts a secondary porosity that is usually even more variable depending on the frequency, orientation, aperture, interconnection and infilling of the fractures.

Table 3-6 summarizes the values of bedrock hydraulic conductivity determined during this program. At two locations, packer testing was conducted at 3 m intervals throughout the upper 23 m to 25 m of the bedrock to define the profile of hydraulic conductivity with depth. Based on hydraulic conductivity values, the bedrock profile has been divided into five hydrostratigraphic units, arbitrarily labelled zones A to E for convenience. Three of the units, zones A, C and E, have higher permeabilities. These are separated by two lower permeability units, zones B and D. These zones are distinguished in Table 3-5 and discussed below.

Zone A is defined as the upper 6 m of bedrock which corresponds with the first two packer test intervals. This zone is likely weathered and therefore would be expected to be more heavily fractured. Slug tests conducted in this zone at twelve on-site locations and four off-site locations established a range of hydraulic conductivities of $1\text{E-}5$ m/s to $4\text{E-}3$ m/s, with a geometric mean of $2\text{E-}4$ m/s. The variability may be attributed to the degree of fracturing encountered at individual locations. A pump test in this zone in the northwest corner of the Preferred Site (borehole 85-1-22) yielded a hydraulic conductivity of $1\text{E-}3$ m/s. A fracture porosity of 0.01 was calculated for Zone A, based on the measured hydraulic conductivity and the observed fracture frequency in rock cores, using the method outlined by Snow (1968).

Zone B comprises the next 3 m thick packer test interval. The geometric mean hydraulic conductivity of this zone is about $2\text{E-}7$ m/s. This interval has sufficiently low permeability to act as an aquitard between Zone A and the underlying two to four packer test intervals (6 m to 12 m thickness, depending on

TABLE 3-6: VALUES OF HYDRAULIC CONDUCTIVITY
BEDROCK AQUIFER

ZONE	BOREHOLE	ELEVATION TESTED (mASL)	HYDRAULIC CONDUCTIVITY (m/s)		
			SLUG TEST	PUMP TEST	PACKER TEST
A	85-1-12	150.13 - 149.13	4E-3	1E-3	
	85-2-1	149.57 - 148.05	2E-4		
	85-3-1	153.24 - 150.55	6E-5		
	85-4-1	148.23 - 147.25	8E-5		
	85-5-1	146.00 - 145.00	2E-4		
	85-6-1	148.24 - 146.72	3E-4		
	85-7-1	146.74 - 145.74	2E-5		
	85-9-1	148.00 - 147.00	2E-3		
	85-10-1	147.07 - 146.07	6E-4		
	85-11-1	143.87 - 142.89	2E-4		
	85-12-1	146.07 - 143.07	2E-3		
	85-13-1	145.35 - 144.35	4E-5		
	85-14-1	140.05 - 139.05	1E-5		
	85-15-1	144.25 - 143.25	8E-5		
	85-16-1	156.15 - 155.15	6E-4		
	85-1	150.26 - 148.26			
	85-1-12	149.53 - 146.53			>6E-5
	85-1-12	146.53 - 143.53			>6E-5
B	85-1-12	143.53 - 140.53			2E-7
	85-12-12	139.19 - 136.19			3E-7
C	85-1-12	140.53 - 137.53			2E-6
	85-1-12	137.53 - 134.53			2E-5
	85-12-12	136.19 - 133.19			1E-5
	85-12-12	133.19 - 130.19			>6E-5
	85-12-12	130.19 - 127.19			>6E-5
	85-12-12	127.19 - 124.19			2E-5
D	85-1-12	134.53 - 131.53			8E-9
	85-1-12	131.53 - 128.53			1E-8
	85-1-12	128.53 - 125.53			8E-9
	85-12-12	124.19 - 121.19			9E-9
	85-12-12	121.19 - 118.19			8E-11
	85-12-12	118.19 - 115.19			<3E-11
E	85-1-12	125.53 - 122.53			3E-7
	85-12-12	114.29 - 111.79			9E-6

NOTES: 6E-5 is the upper limit of the packer testing equipment
3E-11 is the lower limit of the packer testing equipment

location) that have been grouped to form Zone C. Zone C is again more permeable, with hydraulic conductivities ranging from $2\text{E-}6$ m/s to greater than $6\text{E-}5$ m/s, which is the upper limit of the packer testing equipment.

Zone D also acts as an aquitard, with hydraulic conductivities ranging from less than $3\text{E-}11$ m/s, the lower limit of the packer testing equipment, to $9\text{E-}9$ m/s. This zone is about 9 m in thickness based on the packer testing results. Zone D is underlain by another more permeable unit, Zone E. Only one packer interval was tested in Zone E at each location; the resulting hydraulic conductivities ranged between $3\text{E-}7$ m/s and $9\text{E-}6$ m/s.

Zones C and E are also considered to have a secondary porosity. In this case, the secondary porosity results not only from bedding fractures, but also from vugs and gypsum stringers which were observed in the bedrock cores. A "fracture" porosity of 0.05 has been assumed for these zones in order to calculate ground water flow rates.

3.3 GROUND WATER FLOW

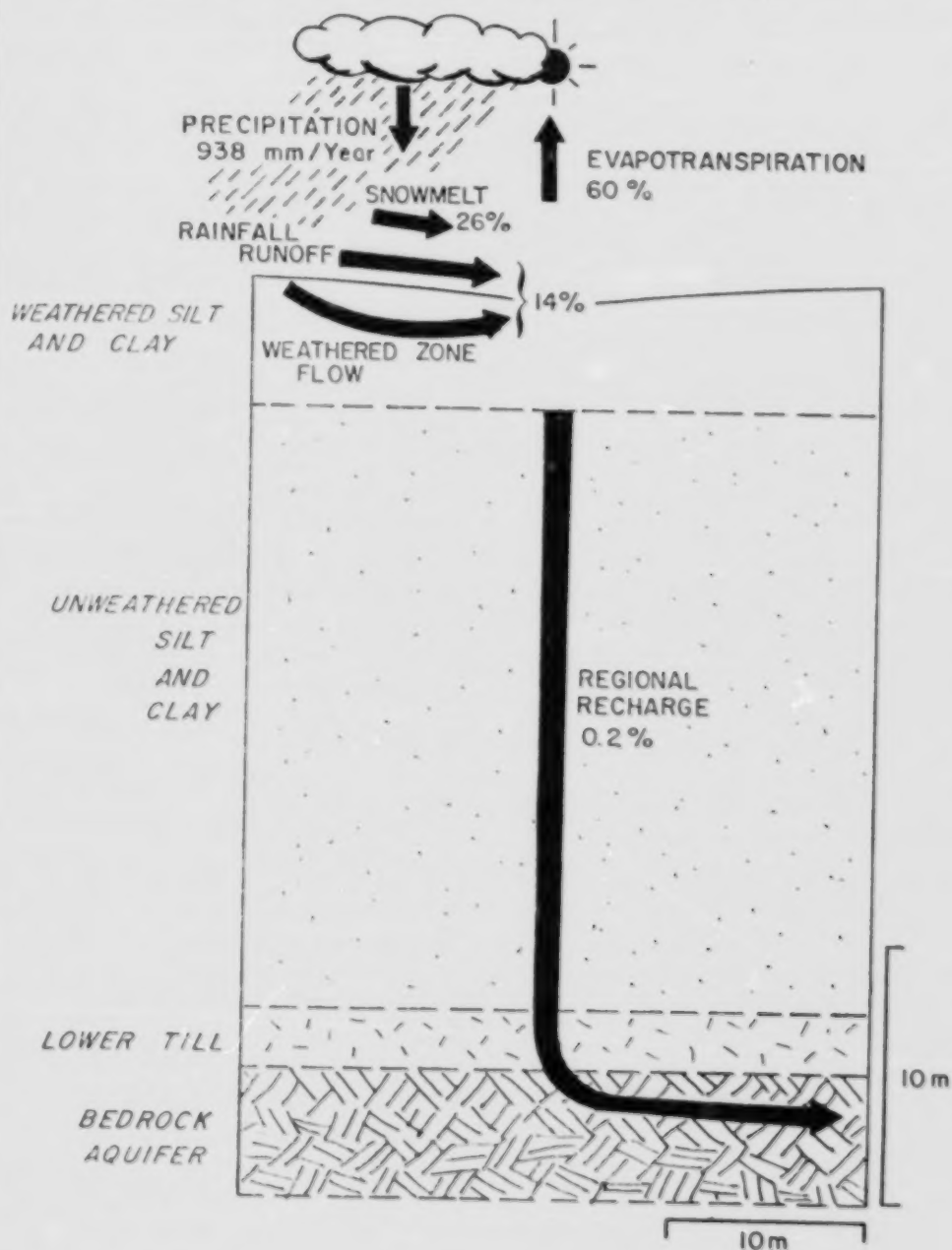
3.3.1 INTRODUCTION

The origin and pattern of movement of ground water at the Preferred Site is described in a regional and local context in this section. Figure 3-1 is provided as a reference that schematically illustrates the following discussion.

Ground water originates from precipitation. It is estimated that approximately 938 mm/year of precipitation falls on the

Figure 3-1

Schematic Overview Of Ground Water Flow



surface of the Preferred Site, per unit area, in an average year. Based on the water budget calculations described in Appendix 13, about 558 mm or 60% of this precipitation evapotranspires. It is also estimated that a minimum of about 243 mm or 26% leaves the site directly as surface runoff during spring melt. The remainder of the precipitation, about 134 mm or 14% in total, either runs off overland to the surface water system during rainfall, or infiltrates.

The surface water system at the Preferred Site consists of a series of low, parallel ridges and swales (Section 2.2.2). The drainage swales are generally 30 m to 100 m apart and the ridge/swale relief is typically less than 2 m. During recharge events (e.g. rainfall) the bulk of infiltration flows laterally through fractures in the weathered silt and clay portion of the Aquitard and discharges into the surface drainage swales. It is estimated that the combined discharge to the swales from the weathered zone and from direct overland runoff (exclusive of snowmelt, as noted previously) is about 14% of the total annual precipitation.

A very small percentage of precipitation, about 0.2% (2 mm/a) moves vertically downward, through the Aquitard into the underlying Bedrock Aquifer. The uniformly low hydraulic conductivity of the unweathered silt and clay, about $2\text{E-}10$ m/s on average, is the primary reason for the low ground water flux. As a result the unweathered silt and clay unit exerts a dominant control on flow throughout the ground water system, and allows the local ground water flow system to be characterized as being highly uniform and predictable.

3.3.2 REGIONAL GROUND WATER FLOW

3.3.2.1 Introduction

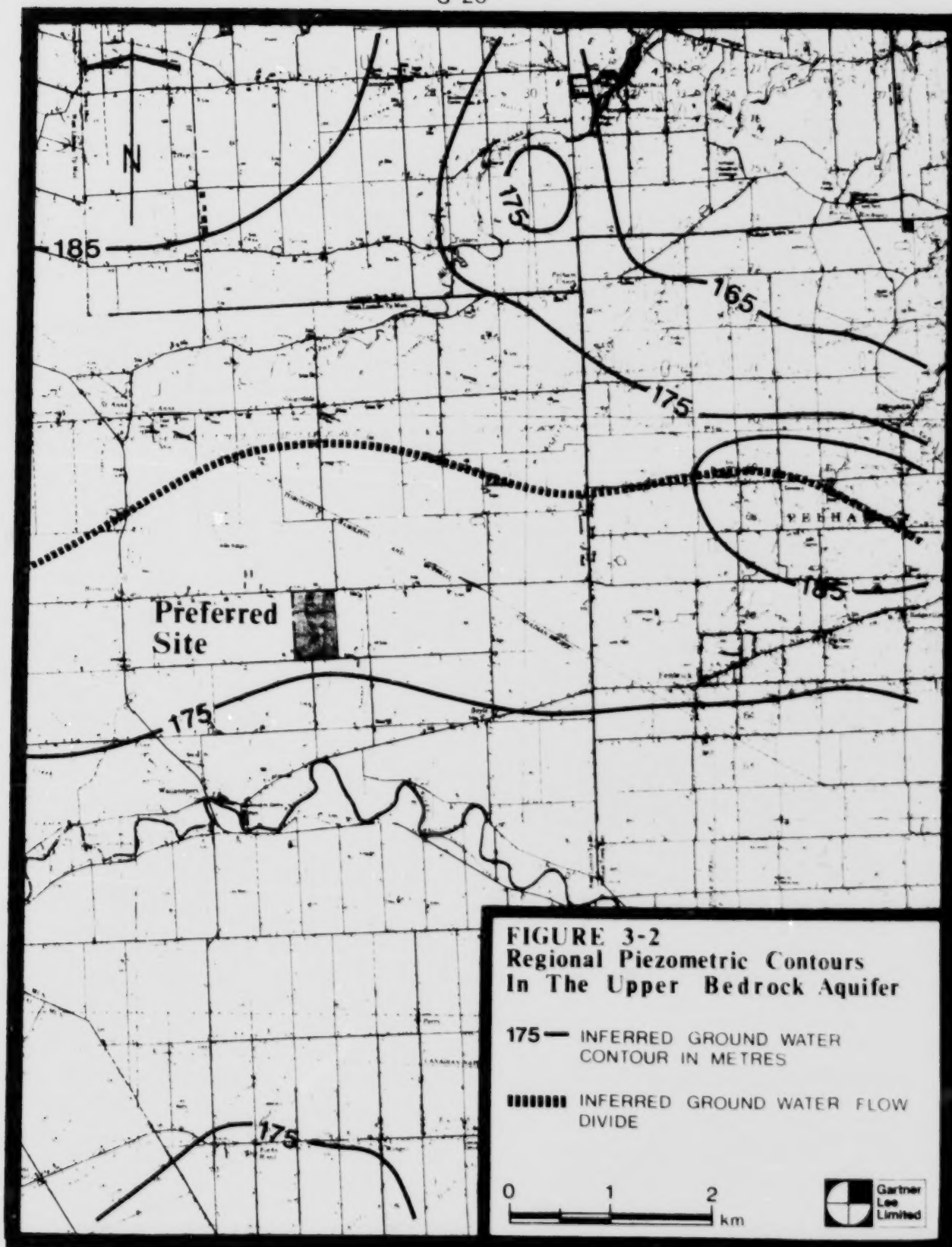
This section describes the regional hydrogeology of the Preferred Site area both to ensure that the site hydrogeology, fits into the regional context, and to assess the ultimate fate of ground water originating as infiltration at the site.

As summarized in Section 3.3.1, about 2 mm/a or 0.2% of precipitation falling at the site moves downward through the aquitard to the underlying Bedrock Aquifer.

In order to determine the subsequent flow directions, selected static water level elevations from the Ontario Ministry of the Environment Water Well Records (MOE, 1978a; 1981) were plotted at a scale of 1:25,000. The selected wells were all completed within the upper few metres of bedrock, and a sufficient number of wells were plotted to allow reasonable contouring of the static water level at a 10 m interval. The study area and the resulting contours are illustrated in Figure 3-2. It should be noted that the contours reflect the regional pattern of ground water flow and are not meant to accurately depict flow in the bedrock on a local scale.

3.3.2.2 Discussion

The Preferred Site is located approximately 3 km south of the regional ground water flow divide identified in Figure 3-2. Immediately north of the divide, ground water flow is northward toward Twenty Mile Creek, whereas south of the divide, ground water flow is southward toward the Welland River. Another more northerly divide exists near the crest of the Niagara Escarpment. This divide separates ground water flow northward toward Lake Ontario and southward toward Twenty Mile Creek.



Ground water flow northeast of the Preferred Site (north of the ground water divide) is down the Niagara Escarpment toward the wide distributary area formed by the valley network of Twelve Mile Creek, Fifteen Mile Creek, Sixteen Mile Creek, and Twenty Mile Creek. Flow in this area may be influenced by the buried bedrock valley identified by Feenstra (1981). The buried valley runs from the Lowbanks-Long Beach area on Lake Erie through Wainfleet and Pelham Corners, to the Jordan Harbour - Port Dalhousie area north of the Escarpment. The influence of the buried valley is evidenced from the closeness of the piezometric contours in the North Pelham - Rockway area (Figure 3-2). The interpretation of the regional ground water movement in this area is consistent with that depicted by Turner (1978).

Ground water flow in the central portion of the Niagara Peninsula is characterized by flat (low) hydraulic gradients. Because of this, the direction of flow and the potential areas of ground water discharge are not easily defined. Flowing wells have been reported in the vicinity of the Welland River (Section 5.0), however, many of these flowing wells were drilled as gas exploration wells and are completed in deeper bedrock zones. Immediately south of the Preferred Site, the Welland River is bedded in fine-grained sediments well above the bedrock surface. Although these sediments restrict the upward movement of ground water from the bedrock, the Welland River may act as a regional divide and discharge point for the bedrock aquifer because of the low gradient and sluggish flow in the rock. However, some ground water movement in the bedrock may also continue southward beyond the Welland or be deflected eastward towards discharge points further along the Welland River.

Local highs are observed in the bedrock static levels north of the Lake Erie shoreline (Figure 3-2). These may function as local ground water flow divides, although their overall relief is very subdued. Although the well data are inconclusive, the Onondaga Escarpment, which occurs discontinuously along the northern shoreline, may also act locally as a divide. Regional flow towards Lake Erie may occur along breaks in the Escarpment.

Haefeli (1972) observed similar hydrogeologic trends in the area south of the Welland River. Based on detailed water level measurements it was concluded by Haefeli that ground water flow in the vicinity of the previously described buried bedrock valley between the Lowbanks-Long Beach area on Lake Erie and Wainfleet, was southward rather than towards Lake Ontario.

In summary, ground water originating at the Preferred Site flows in a southerly direction under very low hydraulic gradients in the upper, more permeable portion of the bedrock. Discharge likely occurs to the Welland River, however, some flow may also continue south of the Welland and/or be deflected eastward to discharge points farther along the river.

3.3.3 LOCAL GROUND WATER FLOW

3.3.3.1 Introduction

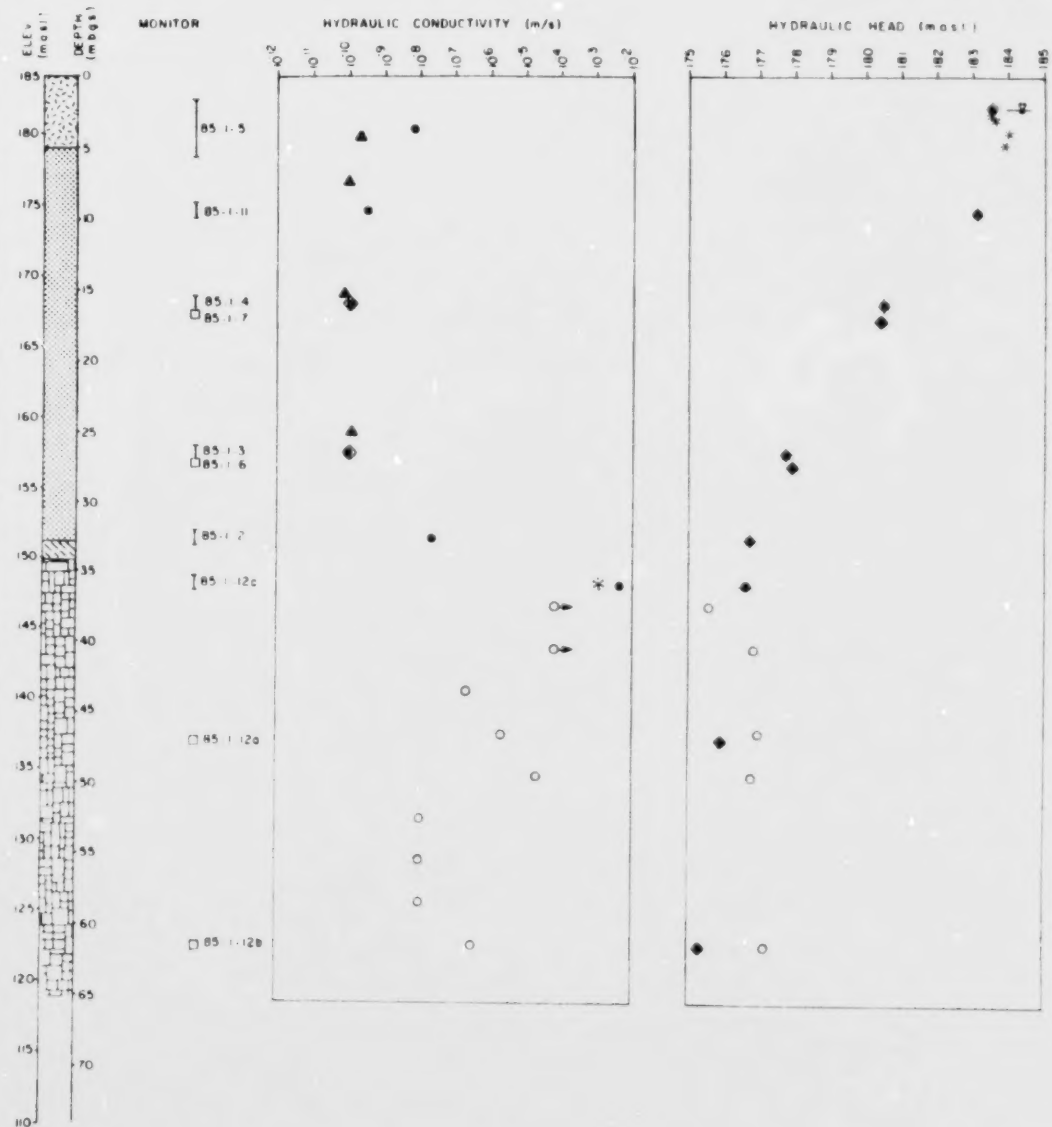
The rates and directions of ground water flow at the Preferred Site were determined by combining information on the hydrogeologic properties of the various hydrostratigraphic units, as presented in Section 3.2, with information on the hydraulic gradients that exist within and between each of the units. Water level measurements used in establishing hydraulic gradients are presented in Appendix F2. Water level measurements were also taken as part of the packer testing to establish the hydraulic head profile in the bedrock (Appendix G3).

Depth profiles of hydrostratigraphy, monitor location hydraulic conductivity and hydraulic head for drilling locations 85-1 and 85-12 are shown in Figure 3-3 and Figure 3-4, respectively. These two locations were selected to illustrate the discussions on local ground water flow because of the large number of water level monitors (11 at each location) and correspondingly comprehensive data base available for each location. The distribution of hydraulic head at these two locations is considered to be representative of that at other drilling locations at the Preferred Site.

Two components of local ground water flow can be clearly distinguished; these are termed shallow flow and deep flow. Shallow flow is transient, responding to day-to-day climatic changes. Shallow flow occurs primarily in the weathered silt and clay unit, although the entire Upper Glaciolacustrine Unit (Section 2.0) has been examined here to fully illustrate the transition from shallow to deep flow with depth. Deep flow can be considered as steady state; that is, the effects of daily climatic variances are minor. Deep flow includes all of the Bedrock Aquifer and the Aquitard excluding the weathered silt and clay.

Deep ground water flow through the Aquitard and Bedrock Aquifer is depicted in cross-section in Figure 3-5. Figure 3-5, constructed along geologic cross-section A-A' (Figure 2-7), is parallel with the regional north-south flow direction (Figure 3-2). Equipotential contours are based on observed water levels in monitors completed at various depths. Ground water flow is perpendicular to the equipotential contours, although consideration must be made for the vertical exaggeration of Figure 3-5. Shallow flow is not depicted in Figure 3-5 since the water levels measured at the site do not represent daily fluctuations. Therefore, the equipotential contours do not extend into the weathered silt and clay unit.

SUMMARY HYDROGEOLOGIC PROFILES FOR DRILLING LOCATION 85-1



LEGEND

- Fractured Silt & Clay
- Unfractured Silt & Clay
- Lower Till
- Bedrock

m a.s.l. Metres above mean sea level

m bgs Metres below ground surface

- Piezometer / Standpipe Screened Interval
- Pneumatic Piezometer

Hydraulic Conductivity Symbols

- Slug Test
- Packer Test
- Pump Test
- Laboratory Test
- Recovery Analysis
- Value Greater Than Shown (upper limit of test equipment)

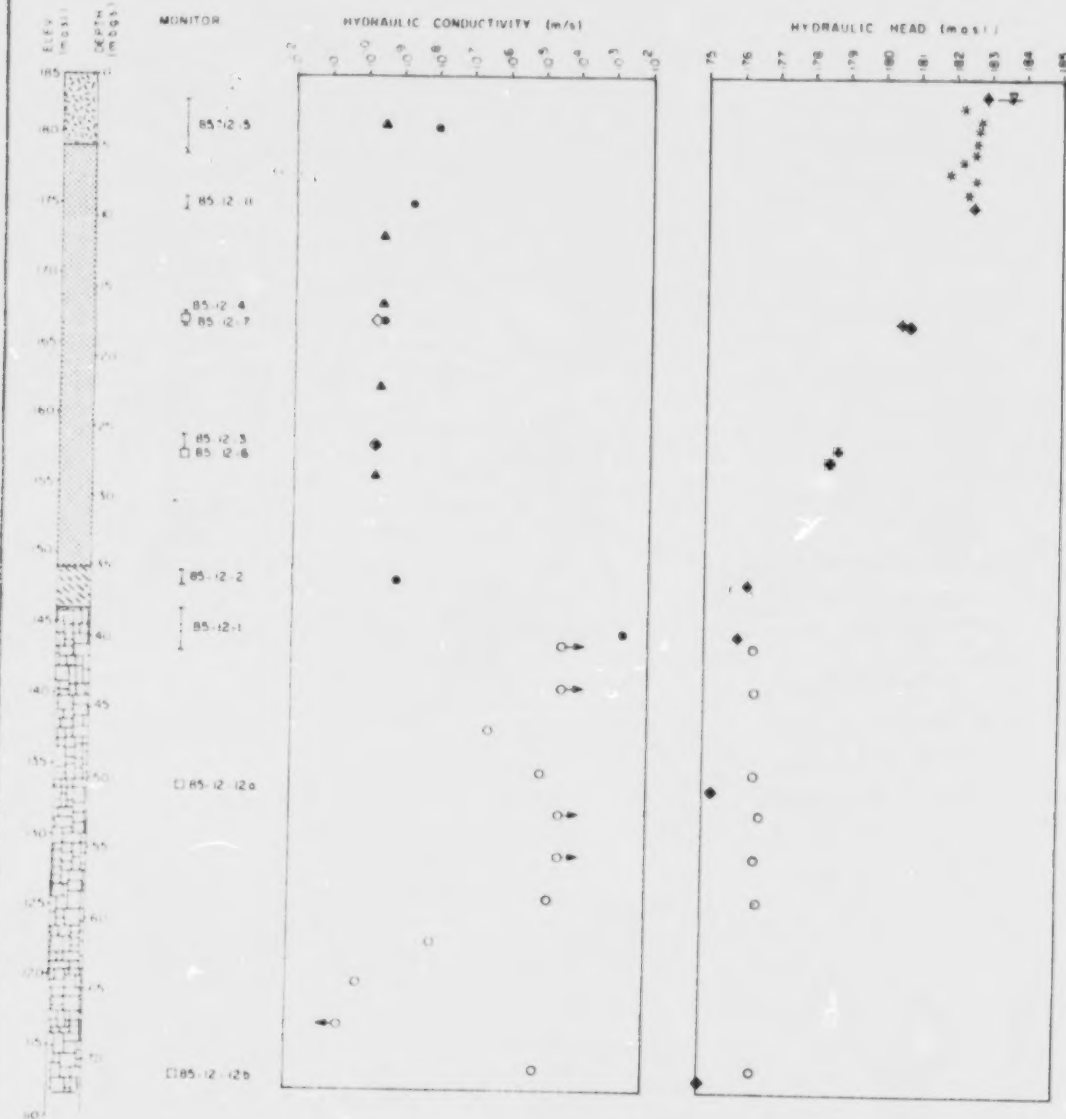
Hydraulic Head Symbols

- Piezometer / Standpipe
 - Pneumatic Piezometer
 - Packer Test
 - Tritium Monitor (July 1986)
 - Water Table
- Hydraulic Head Values Are For March 1986 Except As Noted Above

Figure 3-3



SUMMARY HYDROGEOLOGIC PROFILES FOR DRILLING LOCATION 85-12



LEGEND

Fractured Sil. & Clay

Unfractured Sil. & Clay

Lower Sil.

Bedrock

m a.s.l. Metres above mean sea level

m b.g. Metres below ground surface

Piezometer / Standpipe

Screened Interval

Pneumatic Piezometer

Hydraulic Conductivity Symbols

● Slug Test

○ Packer Test

* Pump Test

▲ Laboratory Test

○ Recovery Analysis

➤ Value Greater Than Shown
(upper limit of test equipment)

➤ Value Lower Than Shown
(lower limit of test equipment)

Hydraulic Head Symbols

◆ Piezometer / Standpipe

◆ Pneumatic Piezometer

○ Packer Test

* Tritium Monitor (July 1986)

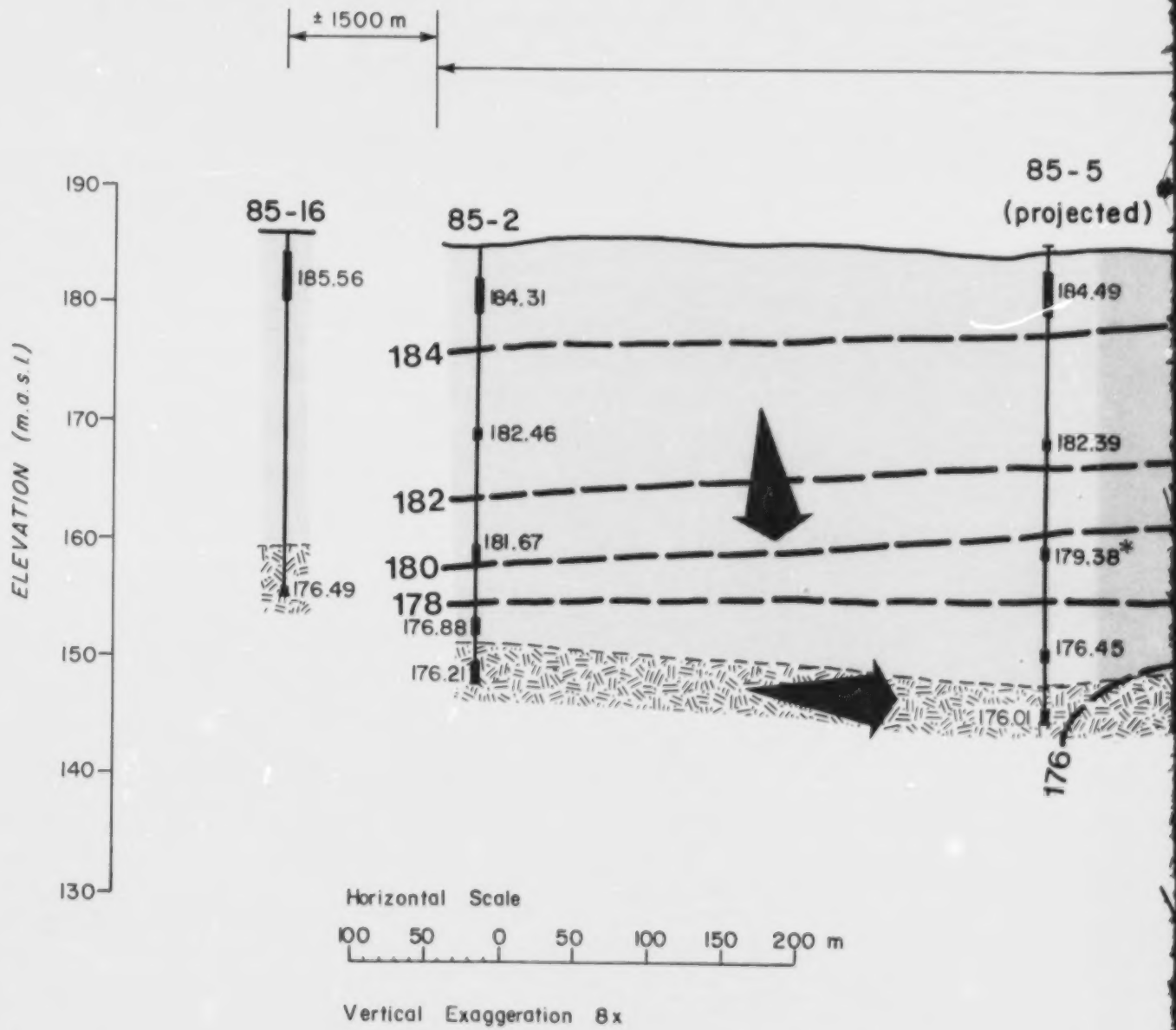
Hydraulic Head Values Are For March 1986
Except As Noted Above

⊠ Water Table

Figure 3-4



A NORTH



Consultant



Legend:

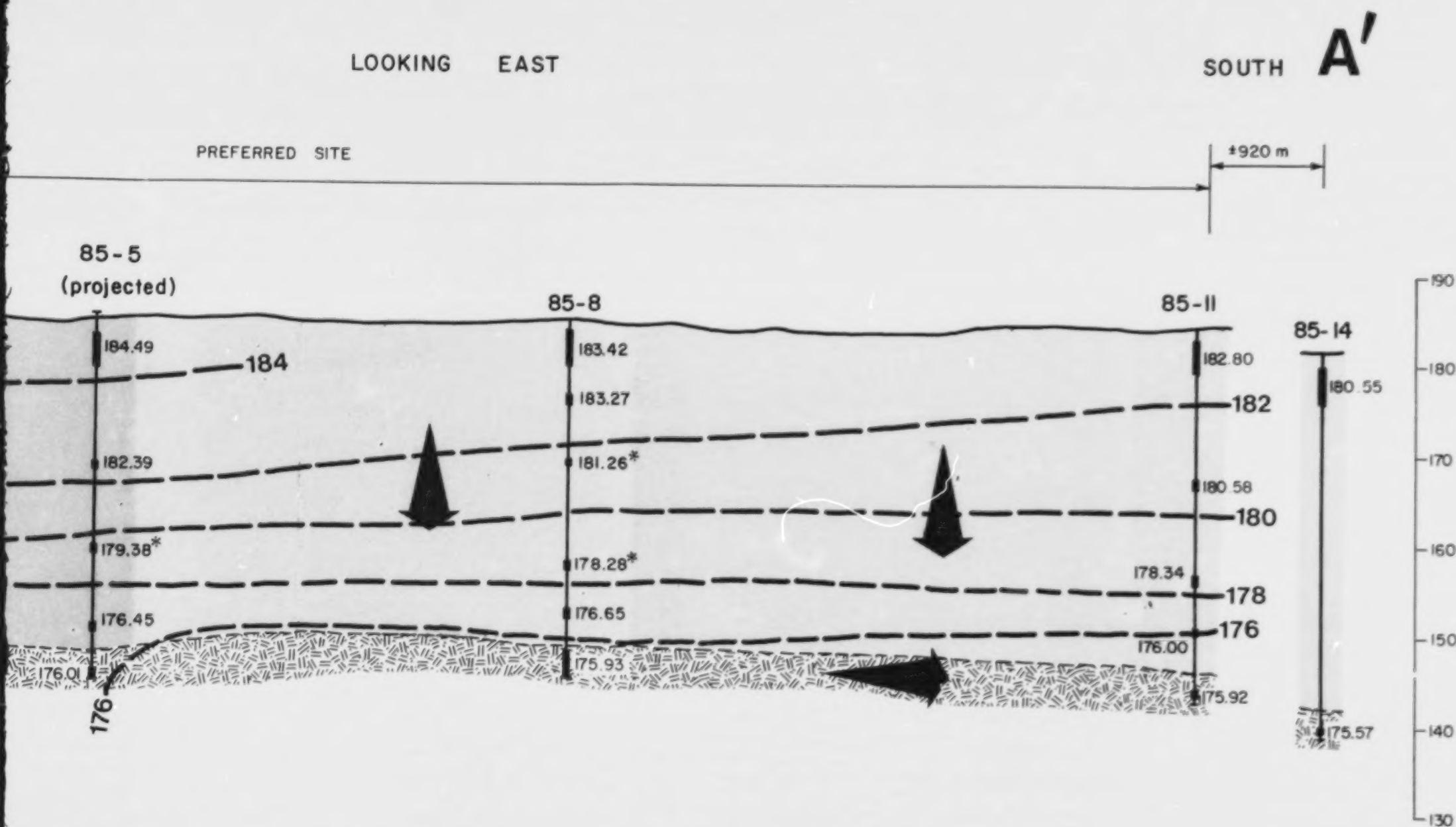
- Aquitard
- Bedrock Aquifer

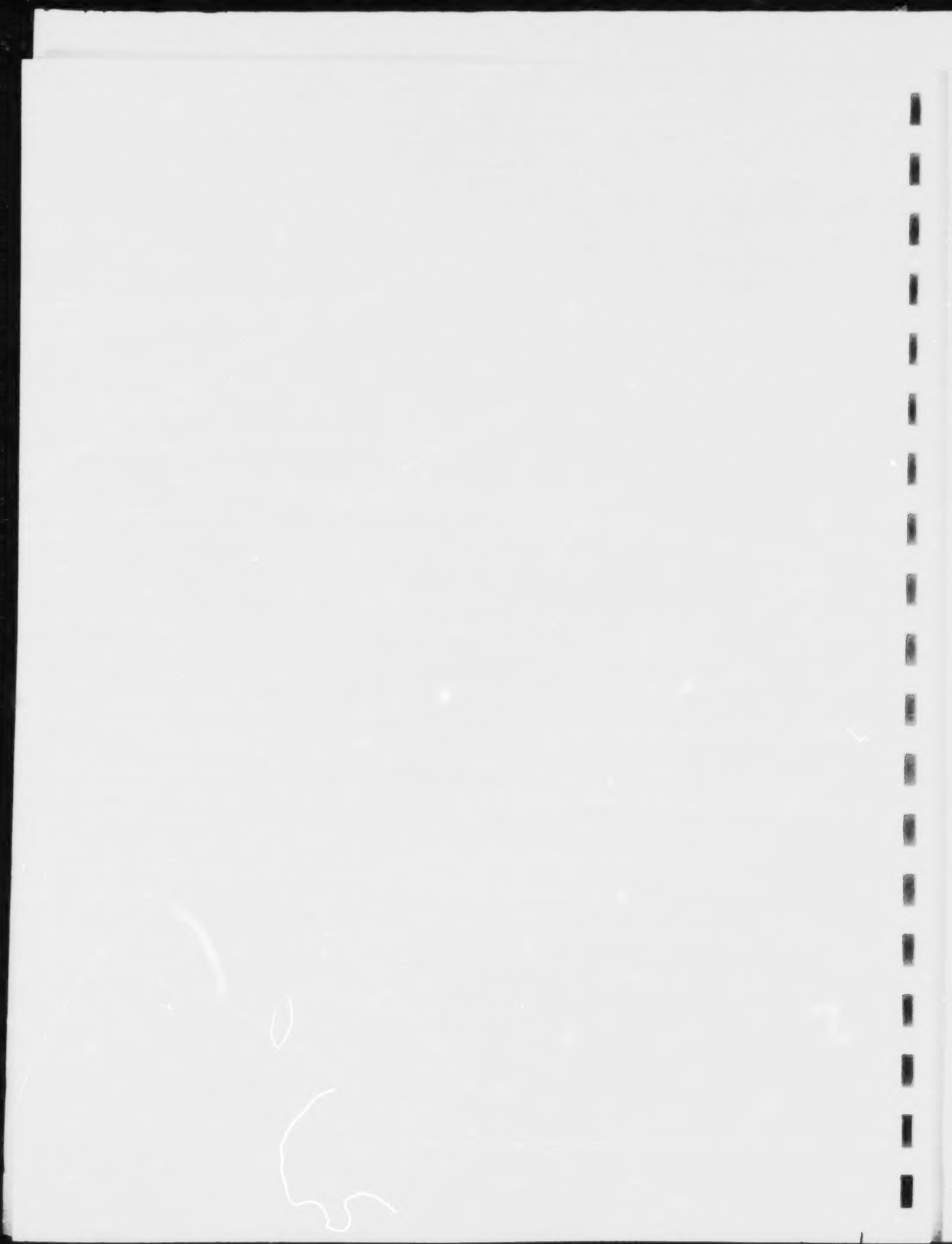
- 85-8** Drilling location (year and number)
- 181.26 Monitor screen location and water level elevation (m.a.s.l.). All values for July 1986.
- 176 Inferred equipotential contour (m.a.s.l.)
- Inferred principal ground water flow direction
- * Monitor not fully recovered, estimated to be within 0.5 m of recovery

Off-site borehole at locations 85-14 and 85-16 have been placed at the ends of the cross-section to illustrate the off-site continuity of the subsurface units. The distance from these borehole locations to the Preferred Site are not to scale on the cross-section

GROUND WATER FLOW PROFILE ALONG CROSS SECTION A-A'

Figure 3-5





The role of each of the hydrostratigraphic units in the local ground water flow system is described in detail in the following sections.

3.3.3.2 Aquitard

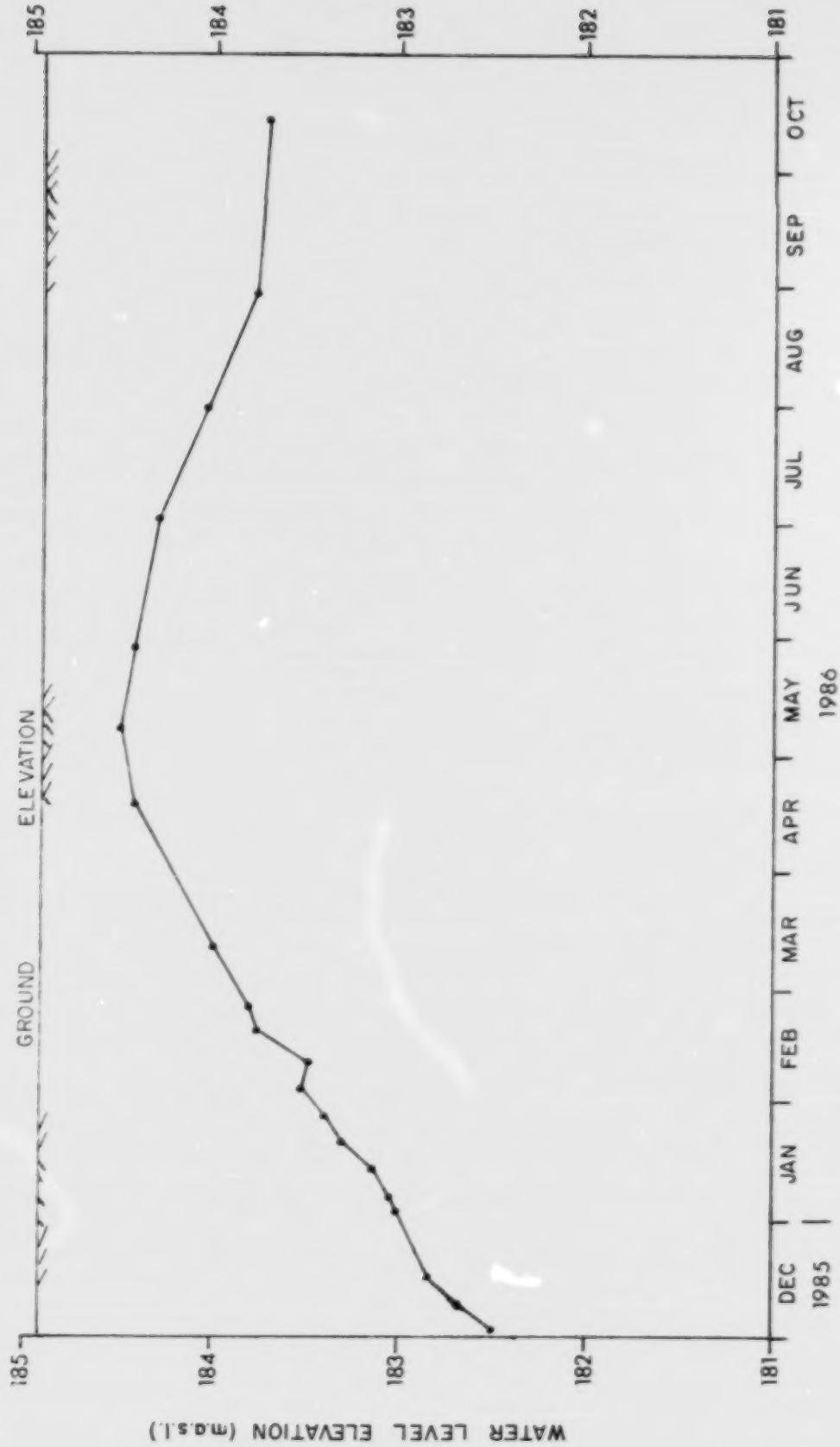
Ground water movement in the Aquitard is influenced by the hydrogeologic properties of the weathered and unweathered silt and clay and the Lower Till, and the distribution of hydraulic head. A discussion of ground water flow in each of the hydrostratigraphic units that comprise the Aquitard follows.

Weathered silt and clay. The interface between the ground water flow system and the surface water system occurs within the weathered silt and clay. Precipitation falling on the site will percolate downward through the unsaturated portion of the weathered silt and clay to the water table.

The elevation of the water table was established using standpipes installed at twelve on-site and four off-site locations. The water table is generally within 1 m to 4 m of ground surface at the Preferred Site and can fluctuate substantially on a seasonal basis. Figure 3-6 presents water table fluctuations for a typical standpipe, 85-2-5, over the eleven month period of record. It is important to note that the silt and clay is likely saturated above the water table due to the presence of a capillary zone (Freeze and Cherry 1979, p. 44-45). The water table fluctuations would have been more extreme had detailed measurements been recorded during recharge events, as discussed below.

During a recharge period (e.g. precipitation or snowmelt), the open fractures are expected to fill rapidly with water, as

Figure 3-6
Water Table Elevation Based On Selected
Data For Standpipe 85-2.5

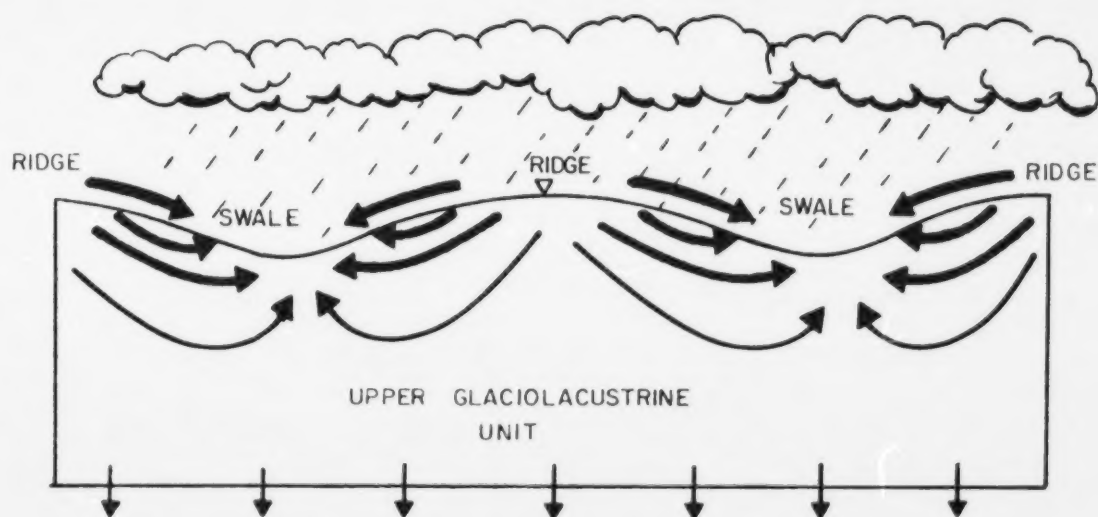


their net overall volume is relatively small and the hydraulic conductivity above the average water table is likely very high (Section 3.2.2.1). This is reflected in a rapid rise in the water table, although the silt and clay matrix between the fractures may be slower to saturate or to drain. The result is a surficial drainage system whereby infiltration along ridges flows through the fractures and discharges to the swales. This flow tends to be shallow, as the hydraulic conductivity in the weathered silt and clay decreases fairly rapidly with depth (Section 3.2.2). This is illustrated schematically in Figure 3-7(a) showing the ground water flow pattern during the "recharge" scenario.

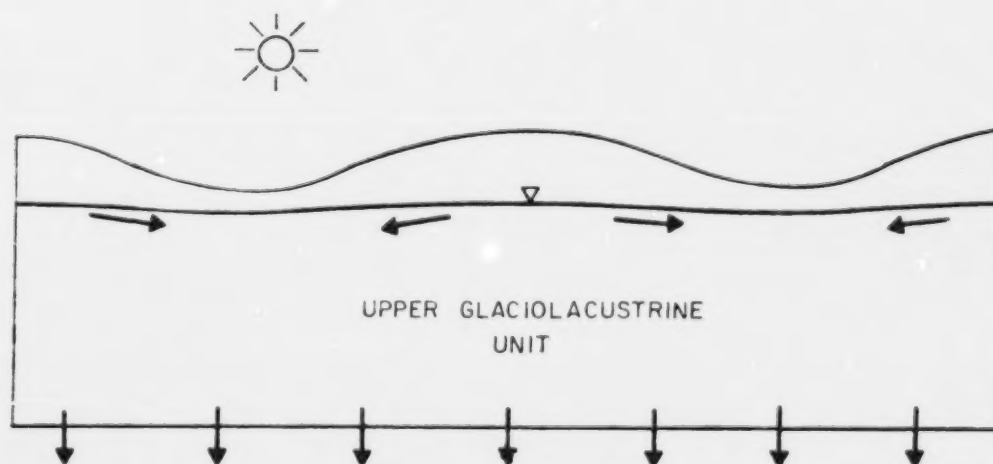
Between recharge events, the greatest portion of the year, the water table exists at or just below the base of the swales and there is minimal discharge to the swales. There may be some lateral flow below the water table in the weathered silt and clay, reflecting local or regional scale topographic trends, but this would be limited since the site is topographically flat and the hydraulic conductivity of the weathered silt and clay decreases with depth. Figure 3-7(b) illustrates the "no recharge" scenario.

It is important to note that in either scenario there is slow but steady flow to depth. The buffering action of the weathered zone to transient recharge events means that deeper flow can essentially be considered as steady state.

Unweathered silt and clay. During both wet and dry periods, the downward movement of water through the weathered silt and clay provides a steady recharge to the underlying unweathered silt and clay. Based on the distribution of hydraulic head,

Figure 3-7**SHALLOW GROUND WATER FLOW SCENARIOS**

(a) "RECHARGE" SCENARIO: water table at surface; recharge at ridges discharging at swales; shallow flow predominates (less than 3 m depth); slow but steady flow to depth.



(b) "NO RECHARGE" SCENARIO: water table flat to gently undulating below base of swales; limited local flow near water table surface; slow but steady flow to depth; this scenario most prevalent throughout year.

ground water movement in the unweathered silt and clay is primarily downward. The principal hydraulic gradient in the unweathered silt and clay is vertically downward. It averages about 0.25, and is reasonably constant with depth. This is demonstrated both by the linear hydraulic head profiles through this unit as shown in Figures 3-3 and 3-4, and by the equipotential contours shown in Figure 3-5.

The lateral gradient in the unweathered silt and clay, across the Preferred Site is extremely small relative to the downward gradient, averaging about 0.001 (Figure 3-5).

The average linear ground water velocity in the unweathered silt and clay unit is estimated to be about 3.8 mm/a vertically downward. The specific discharge is calculated to be about 1.6 mm/a (Appendix I1).

Lower Till. The material properties of the Lower Till are quite variable, as noted in Section 3.2.2. For this reason, ground water flow rates in this unit are also considered to be variable.

In general, ground water flows downward through the Lower Till towards the bedrock. At locations where the Lower Till is reasonably homogeneous, it is expected that this flow would be primarily vertical under gradients comparable to those in the unweathered silt and clay. However, where granular layers exist in the Lower Till, these could be hydraulically continuous with the bedrock. Ground water flow through these granular layers directly to the bedrock would be very rapid.

Assuming a hydraulic conductivity of $2E-8$ m/s, a gradient

of 0.25, which is equivalent to the gradient in the unweathered silt and clay, and a porosity of 0.16, the average linear ground water velocity in the Lower Till is calculated to be about 990 mm/a and the specific discharge is calculated to be about 160 mm/a vertically downward (Appendix 11). Because of the variable nature of the Lower Till, however, these values are considered to be gross estimates only.

3.3.3.2 Bedrock Aquifer

The hydraulic head profile in the bedrock was established by packer testing conducted at locations 85-1 and 85-12 (Figures 3.3 and 3.4). The hydraulic head remains relatively constant with depth, consequently vertical gradients in the bedrock are considered to be very small.

Most of the ground water flow in the bedrock is lateral. The hydraulic conductivity profiles shown in Figures 3.3 and 3.4. indicate zones of higher hydraulic conductivity (identified as A, C, and E for discussion purposes) separated by hydrostratigraphic units of lower hydraulic conductivity (identified as B and D), as discussed previously in Section 3.2.3. Lateral ground water flow in the bedrock would be expected to occur primarily through the higher permeability zones.

The uppermost higher permeability zone in the bedrock, Zone A, has been examined in some detail using twelve on-site and four off-site monitors. Figure 3-8 shows the potentiometric surface of the upper bedrock (Zone A) for the site. The hydraulic head map indicates that ground water flow is generally to the south. The hydraulic gradients, indicated by the relative spacing between adjacent contour lines, are somewhat

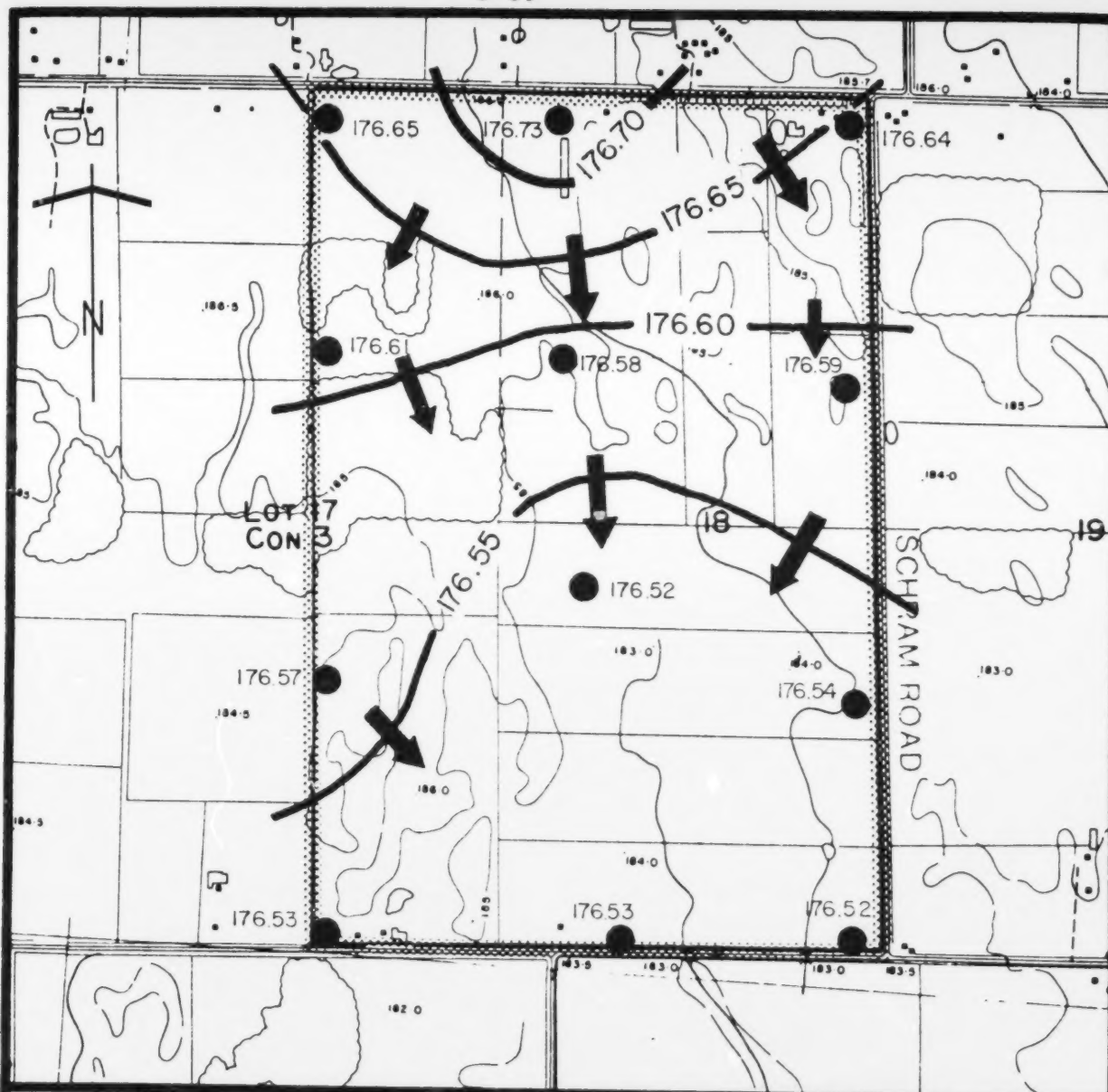


Figure 3-8

HYDRAULIC HEAD DISTRIBUTION IN THE UPPER BEDROCK ZONE (Zone A)

Legend

● 176.61 Measured Hydraulic Head (bedrock water level) March, 1986 (m. A.S.L.)

176.65— Hydraulic Head Contour (contour interval = 0.05 m)

➔ Inferred Principal Ground Water Flow Direction In Bedrock Aquifer

0 100 200 300 400 500 m

variable. The hydraulic gradients based on Figure 3-8 are greater in the northern part of the site (0.0004) and diminish towards the southern part of the site (0.00003). The overall north-to-south gradient calculated between boreholes 85-2-1 and 85-11-1 is about 0.0002.

The specific discharge is estimated as 1.3 m/a (to the south) in the upper bedrock zone using average values for hydraulic conductivity and gradient (Appendix I1). The actual average linear ground water velocity may be greater than this if continuous flow occurs through the fractures. Using the calculated fracture porosity 0.01, the resulting average linear ground water velocity is estimated as 130 m/a to the south.

Ground water flow in the other two higher permeability units was also examined. Based on data from the two deepest boreholes, 85-1-12 and 85-12-12, it appears that the principal hydraulic gradients are also southward in Zones C and E, increasing slightly with depth, 0.0003 and 0.0005 respectively. The resulting values of specific discharge are estimated as >0.19 m/a for Zone C (hydraulic conductivity $>2E-5$ m/s) and 0.032 m/a for Zone E (hydraulic conductivity $2E-6$ m/s), both to the south. Average linear ground water velocities have been calculated for zones C and E based on an assumed "fracture" porosity of 0.05. They are >3.8 m/a and 0.63 m/a, respectively, to the south.

Hydraulic heads were not measured in the lower permeability bedrock units, Zones B and D, due to their slow water level response during packer testing. Therefore, it is not possible to establish hydraulic gradients, specific discharges, or average linear ground water velocities for these units.

3.3.4 GROUND WATER FLOW SIMULATION

FLONET, a two-dimensional computer model developed by E. Frind and G. Matanga of the Ground Water Research Institute, University of Waterloo, was used to simulate ground water flow at the Preferred Site. The purposes of the simulations were twofold:

- (1) to confirm the deep ground water flow pattern interpreted from the field data (shown on Figure 3-5); and
- (2) to predict the nature of shallow ground water flow.

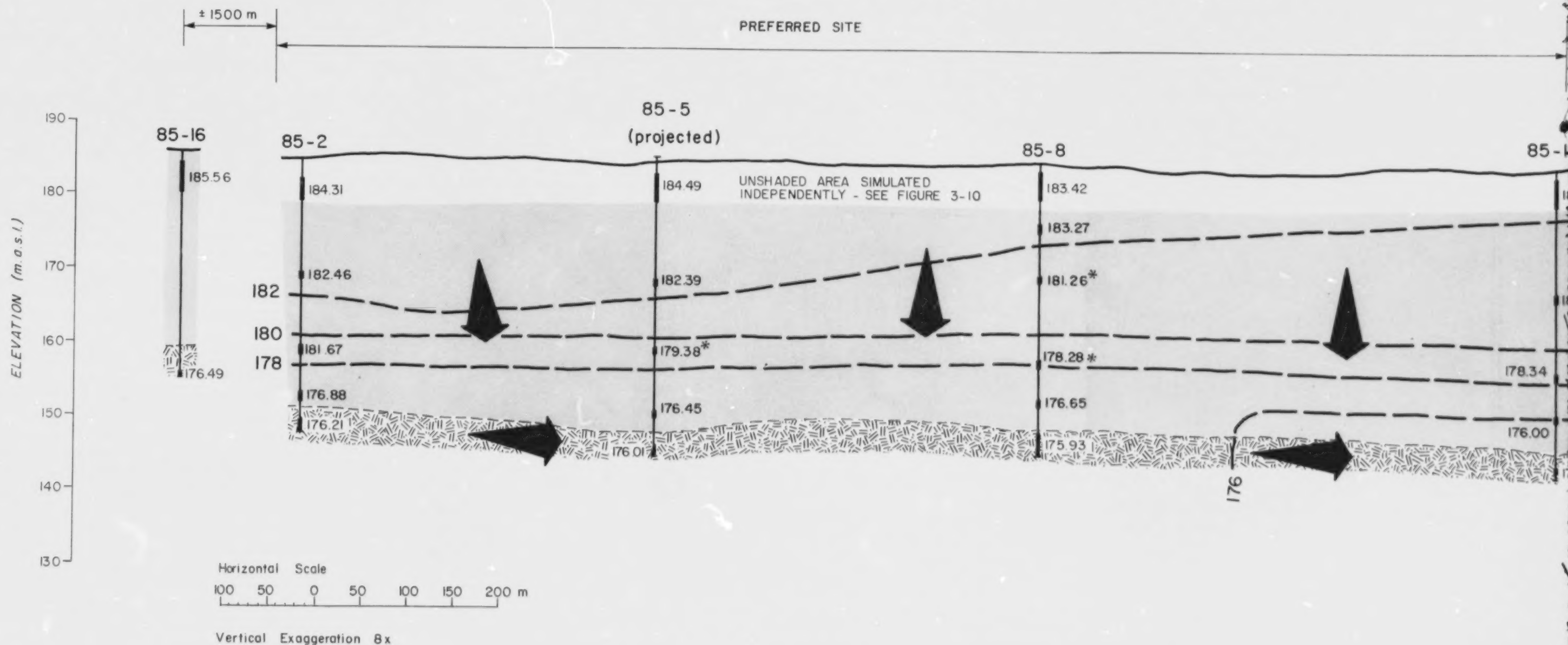
Appendix I1 of this report provides a detailed description of the FLONET computer model as well as the results of the ground water flow simulations. The following is a discussion of the modelling results.

Figure 3-9 shows the results of the ground water flow simulation along a north-south cross-section through the centre of the Preferred Site. The simulation includes the Bedrock Aquifer and that portion of the Aquitard below the base of the Upper Glaciolacustrine Unit as defined in Section 2.0. Flow in the Upper Glaciolacustrine Unit, which includes the weathered zone, was modelled separately and is discussed below.

The results of the computer simulation were transferred onto the same cross-sectional profile as Figure 3-5, which shows the equipotential contours interpreted from the observed water levels at the site. Comparison of Figures 3-5 and 3-9 indicates close agreement between the results. The simulated hydraulic head contours can be seen to conform reasonably well with the observed hydraulic head values at the ground water monitors in Figure 3-9 as well. Thus, the modelling confirms the deep ground water flow pattern described in Section 3.3.3.

A NORTH

LOOKING EAST



Consultant



Legend :



Aquifer



Bedrock Aquifer (Zone A)

85-8

Drilling location (year and number)

181.26

Monitor screen location and water level elevation (m.a.s.l.). All values for July 1986.

176

Simulated equipotential contour (m.a.s.l.)



Inferred principal ground water flow direction

*

Monitor not fully recovered, estimated to be within 0.5 m of recovery

Off-site borehole at locations 85-14 and 85-16 have been placed at the ends of the cross-section to illustrate the off-site continuity of the subsurface units. The distance from these borehole locations to the Preferred Site are not to scale on the cross-section

SIMULATED GROUND WATER FLOW PROFILE ALONG CROSS SECTION A-A'

Figure 3-9

SOUTH **A'**

*920 m

85-11

182.80

182

180.58

180

178.34

178

176

176.00

175.92

85-14

180.55

175.57

190
180
170
160
150
140
130

Shallow flow is transient, as evidenced by water table fluctuations. The two extremes are described as the "recharge" and "no recharge" scenarios in Section 3.3.3 (illustrated in Figure 3-7). The ground water flow pattern for the recharge scenario was established using the FLONET model. The details of this modelling are presented in Appendix I2-4.

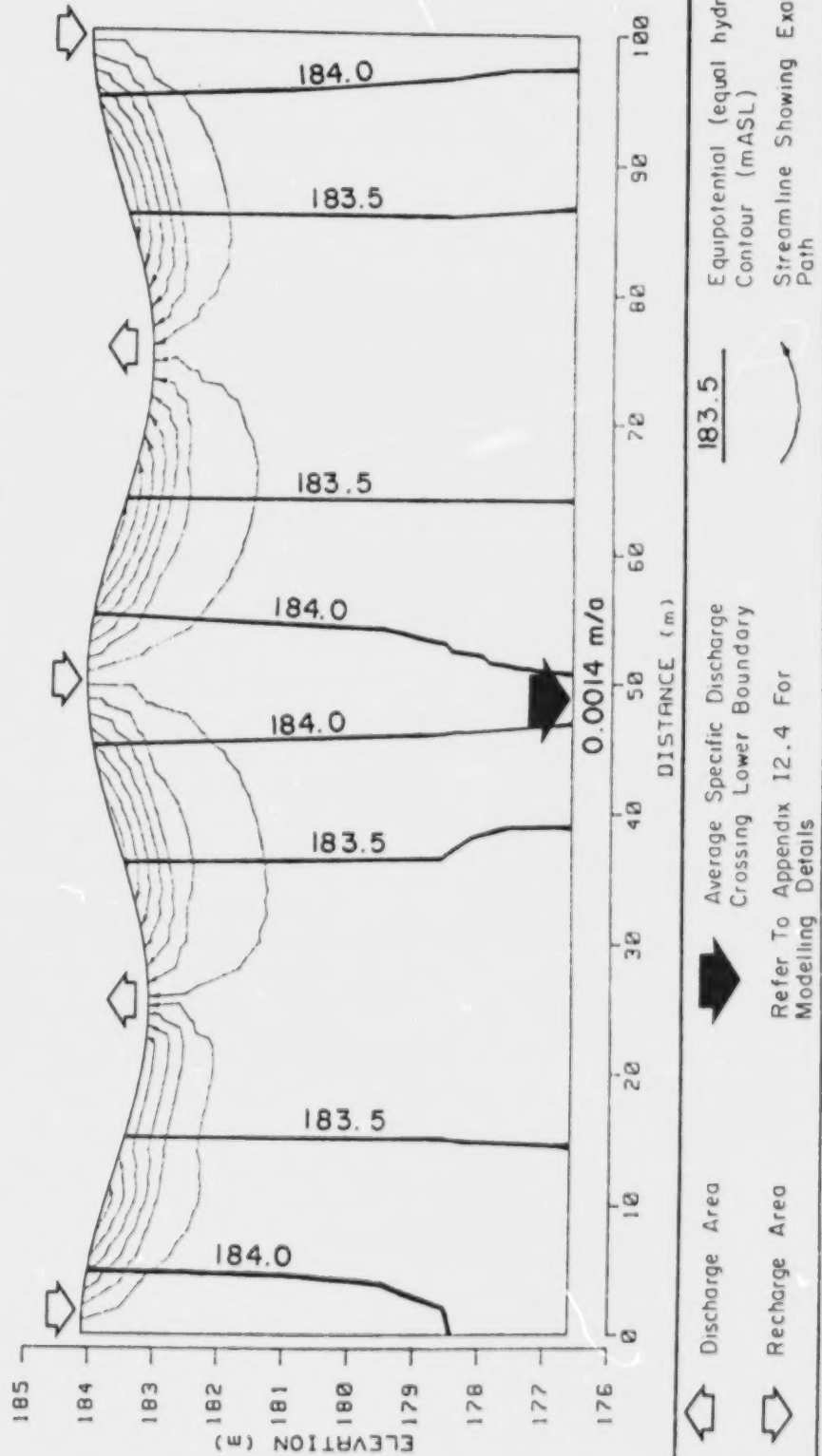
Figure 3-10 illustrates the results of the modelling for a typical generic cross-section through the Glacio-equipotential (equal hydraulic head) Unit. Both equipotential adjacent streamlines) are shown. Average values of recharge/discharge and flow to depth are indicated in Figure 3-10 as well. Note that the flow to depth from the base of the shallow flow modelling matches the inflow along the upper surface of the deep flow modelling (Figure 3-9).

The modelling results support the following conclusions regarding the shallow flow "recharge" scenario:

- hydraulic head is reasonably constant from surface to the base of the Upper Glaciolacustrine Unit, indicating predominantly lateral ground water flow (a similar head pattern was noted in field water level measurements, see Figures 3-3 and 3-4);
- the streamlines show that the bulk of infiltration occurring at the ridges flows in the shallow sub-surface (less than 3 m depth) and discharges at the swales;
- There is a slow, steady component of flow from the base of the section to depth that equals the observed flow rate in the unweathered silt and clay.

Figure 3-10
SHALLOW FLOW MODELLING RESULTS - HYDRAULIC HEAD
AND STREAMLINE DISTRIBUTIONS

AVERAGE SPECIFIC RECHARGE RATE AT RIDGES = 0.092 m/a
AVERAGE SPECIFIC DISCHARGE RATE AT SWALES = 0.079 m/a



4-1

4.0 GROUND WATER CHEMISTRY



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4.0 GROUND WATER CHEMISTRY

4.1 INTRODUCTION

4.1.1 PURPOSE AND SCOPE

This section summarizes the ground water chemistry at the Preferred Site. It also provides interpretations of the chemistry with respect to the geologic and hydrogeologic units outlined in previous sections; ground water flow directions and velocities; quality of ground water resources and migration of naturally occurring solutes dissolved in the ground water.

There were three main objectives of the ground water chemistry study. These were:

- (1) to characterize mainly the inorganic and isotopic composition of existing (background) ground water quality.
- (2) to interpret ground water isotope results with respect to the probable depth of active ground water flow in the near surface, and
- (3) to determine from the ground water isotope results if downward ground water flow and solute transport through the overburden is sufficiently slow that ground waters at depth are old.

The ground water chemistry section is divided into the following subsections. Section 4.1 is the Introduction which describes the Purpose and Scope (Section 4.1.1), Background (Section 4.1.2) and Study Methodology (Section 4.1.3). Section

4.2 summarizes existing ground water chemistry for both the overburden (Section 4.2.1) and bedrock (Section 4.2.2). Section 4.3 provides interpretations of the environmental isotope results. Section 4.3.2 discusses the tritium results as an indicator of the near surface zone of active ground water flow. Section 4.3.3 discusses the naturally occurring oxygen-18 and deuterium profiles in the overburden as indicators of slow downward ground water velocities and solute transport. Section 4.3.4 discusses the results of radiocarbon dating on deep ground waters in the overburden materials.

4.1.2 BACKGROUND

Except for general comments regarding water quality reported in water well logs (i.e. "fresh", "sulphurous" etc.), no ground water chemistry or quality information was collected for the Preferred Site and the surrounding area in previous phases of OWMC's site selection process.

4.1.3 STUDY METHODOLOGY

The methods by which ground water chemistry data were collected are briefly outlined below. A detailed description of the ground water sampling program is given in Appendix B. This appendix outlines ground water monitor flushing procedures, ground water sampling procedures, sample preservation, transportation and chain of custody, pore water squeezing, analytical methods and the quality assurance/quality control program.

A search for ground water quality information in the vicinity of the Preferred Site was undertaken by contacting local and regional offices of the Ministry of the Environment, contacting Dr. I. Brindle at Brock University and reviewing published literature for the area and similar hydrogeologic settings.

A total of 38 monitors were installed specifically for ground water sampling (see Appendices A2 and F1 for chemistry monitor details). Eight of these monitors could not be used for sampling because cement grout leaked into the annulus around the screen. These monitors were identified by anomalously high ground water pH's (>10). The elevated pH's persisted, even after repeated flushing of the monitors. Appendix B summarizes the monitors affected by cement, and discusses the probable reason for cement interferences. Where the smaller diameter monitors installed for water level measurements and hydraulic conductivity testing were not influenced by grout, these were sampled in place of the affected chemistry monitors.

Ground water samples were collected from water quality monitors placed at various depths throughout the overburden and in the upper 3 m of the bedrock. A total of 36 monitors were sampled (5 bedrock and 31 overburden), distributed over five on-site locations (Figure 4-1). Sampling and chemical analyses consisted of:

- (1) all 36 monitors sampled twice for detailed inorganic and general chemistry (see Table 4-1 for parameters),
- (2) all 36 monitors sampled at least once for dissolved methane,
- (3) one bedrock monitor sampled for a scan of organic parameters on the U.S. Environmental Protection Agency's priority pollutant list,
- (4) all 36 monitors sampled once for oxygen-18 and deuterium isotopes, plus a second sampling only of the five bedrock monitors,

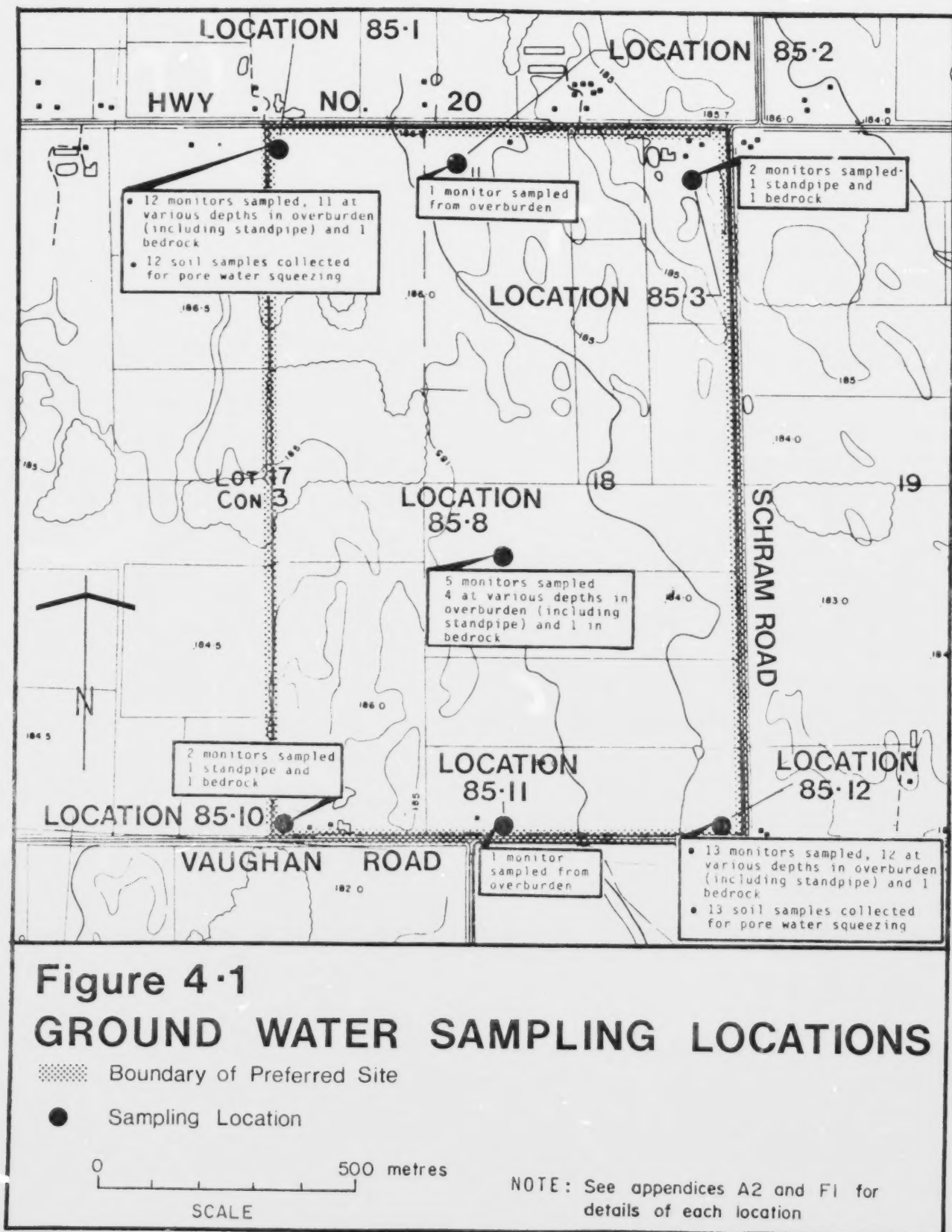


**TABLE 4-1: PARAMETERS ANALYZED FOR DETAILED INORGANIC
AND GENERAL CHEMISTRY**

1. GENERAL CHEMISTRY AND MAJOR IONS

pH (field), temperature (field), electrical conductivity (field), total dissolved solids, dissolved inorganic carbon, dissolved organic carbon, alkalinity, calcium, potassium, magnesium, sodium, silicon, strontium, fluoride, chloride and sulphate.

2. MINOR IONS

silver, aluminum, boron, barium, beryllium, cadmium, cobalt, chromium, copper, iron, manganese, molybdenum, nickel, phosphorus, lead, thorium, titanium, vanadium, zinc, zirconium, bromine, nitrite, nitrate, phosphate and sulphide.

- (5) all 36 monitors sampled at least once for direct counting of tritium,
- (6) 18 monitors (5 bedrock, 13 overburden) sampled once for enriched counting of tritium,
- (7) 4 selected monitors in the overburden sampled for enriched counting of very low level tritium activity, and
- (8) 2 monitors, 25 m deep in the overburden, sampled for carbon-14 activity and carbon-13 composition of carbonate dissolved in the ground water.

Results of all chemical analyses are tabulated in Appendix J.

Soil samples, representing depth profiles at two locations (Figure 4-1), were also collected for pore water squeezing and analysis of the pore water for chloride and the isotopes oxygen-18 and deuterium. Results of chemical analyses on the pore water are tabulated in Appendix J.

4.2 EXISTING GROUND WATER CHEMISTRY

The main purpose of this section is to describe the existing or background ground water chemistry at the Preferred Site.

Interpretation of the results is provided with respect to quality of ground water resources, geochemical processes such as weathering and comparison to published chemistry data for similar hydrogeologic settings in Ontario.

This section is divided into two main parts. The first (4.2.1) discusses ground water quality in the overburden. The second (4.2.2) discusses ground water quality in the bedrock.

4.2.1 OVERBURDEN GROUND WATER CHEMISTRY

Ground water samples were collected on two occasions from monitors at various depths in the overburden. Water table monitors (standpipes) at five locations (Figure 4-1) were sampled to characterize average ground water quality in the near surface weathered zone. The standpipes were screened to a depth of 5.3 m, which is about the average depth of observable weathering, based on a change in soil colour. In addition, nests of shallow piezometers were sampled at locations 85-1 and 85-12 to establish detailed profiles of chemistry changes through the weathered portion of the silt and clay and into the upper portion of the unweathered silt and clay. These piezometers were completed to depths of 1.4, 2.4, 2.9, 3.9, 4.7, 5.4, 6.2, 6.9 and 7.8 m. At locations 85-1, 85-8 and 85-12, piezometers were also sampled from depths of approximately 9 m, 16 to 17 m and 25 to 26 m to establish ground water chemistry trends deeper in the unweathered silt and clay. Results of chemical analyses on the ground water samples are tabulated in Appendix J.

Profiles of major ion concentrations with depth are shown in Figures 4-2 and 4-3 for locations 85-1 and 85-12 respectively. The points shown are the average of two sampling runs and are plotted at the midpoint of the monitor's screened interval. Results from location 85-8 (not shown) were similar to location 85-12.

Ground waters in the upper 9 m are characterized by very high concentrations of total dissolved solids (TDS), sulphate (SO_4) and magnesium (Mg) plus high concentrations of bicarbonate (HCO_3), sodium (Na) and calcium (Ca). Below this

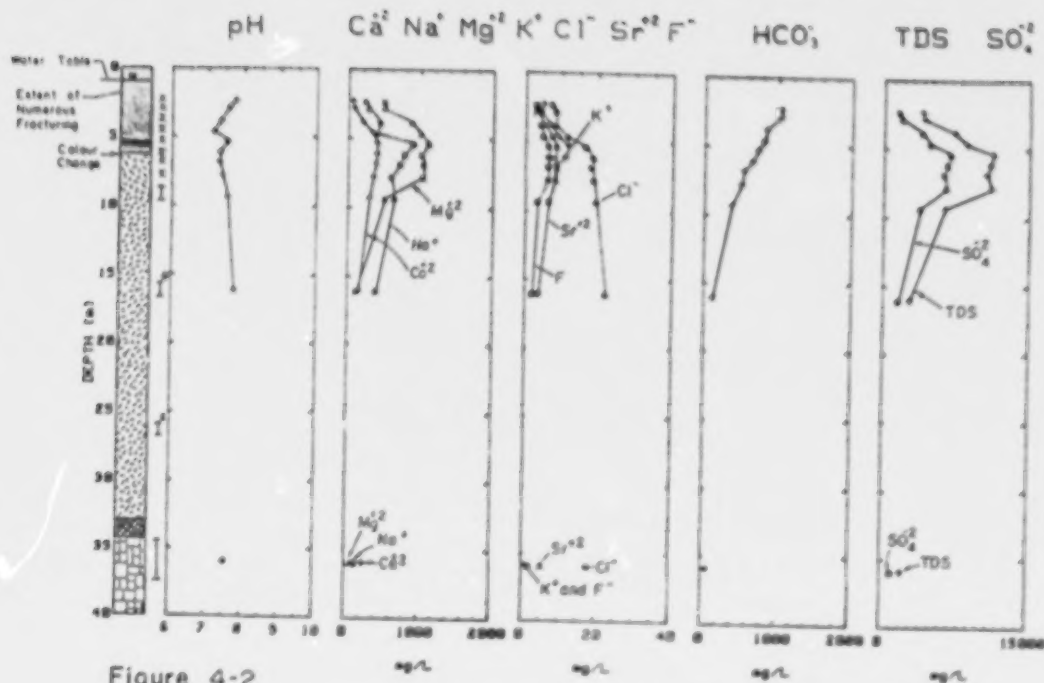


Figure 4-2

MAJOR ION CONCENTRATIONS OF GROUND WATER AT LOCATION 85-1

* results from monitor 2-4 at location 85-2 used because of cement interferences in 85-1-9 and 85-1-4

• no data because of cement interferences

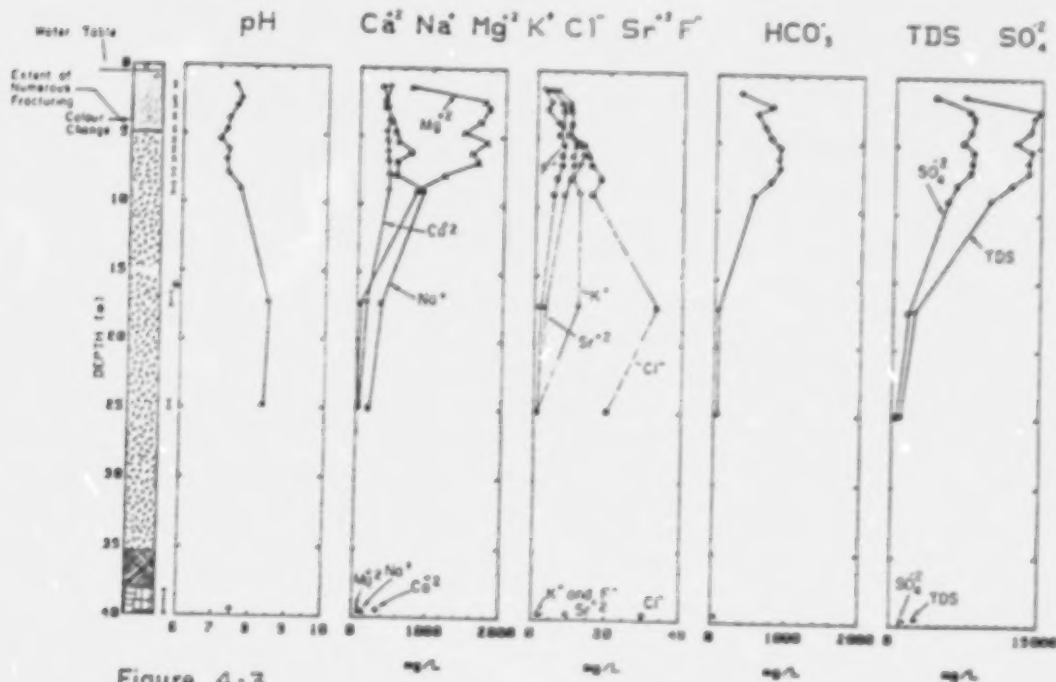


Figure 4-3

MAJOR ION CONCENTRATIONS OF GROUND WATER AT LOCATION 85-12

LEGEND
 [] Weathered silt and clay [] Unweathered silt and clay [] Lower Till (Silt and sand till)
 [] Dolomite bedrock [] Screened interval of monitor

* results from monitor 11-4 at location 85-11 used because of cement interferences in 85-12-9 and 85-12-4

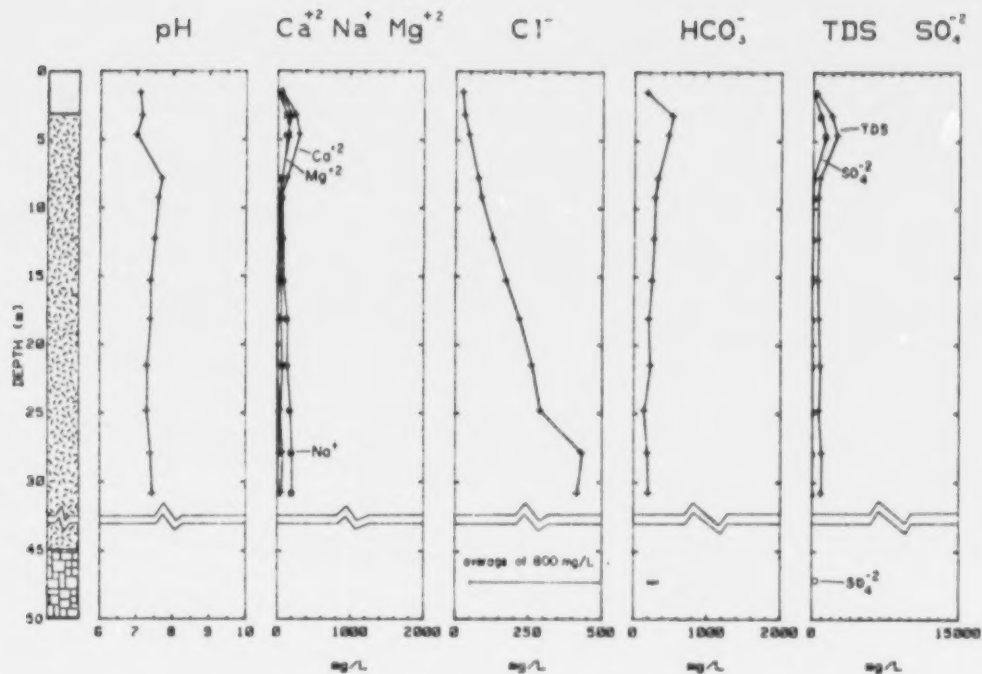
depth, concentrations of the above constituents decline rapidly with depth, reaching levels approximately 5 to 15 times lower at a depth of 25 m. Although concentrations differ, similar trends of ground water chemistry in clayey overburden materials have been reported by: (1) Heystee et al. (1982), Desaulniers et al. (1981) and Desaulniers (1980) for "waterlain" clayey tills in southwestern Ontario; (2) by Bradbury et al. (1985) for clayey till in northwestern Wisconsin and (3) by Desaulniers et al. (1981) and Desaulniers (1980) at Wainfleet, Ontario. The Wainfleet site is underlain by a similar sequence of overburden materials at the Preferred Site. For example, Figure 4-4 shows the trends of major ion concentrations with depth reported in Desaulniers (1980) for Sarnia, Ontario, compared to location 85-12 at the Preferred Site. Comparisons between the Preferred Site and data reported in the literature are discussed in more detail in subsequent sections.

For ease of discussion, ground waters above 9 m depth at the Preferred Site will be referred to as shallow overburden ground waters, and those below as deep overburden ground waters. The characteristics of these ground waters are discussed in more detail in the following sections.

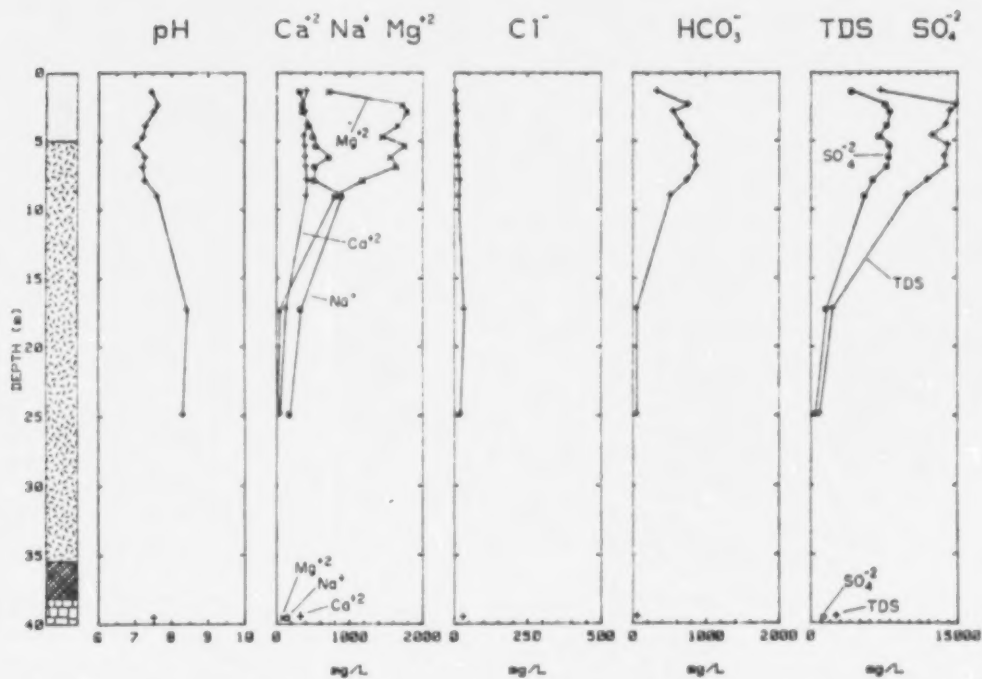
4.2.1.1 Shallow Overburden Ground Waters

Major Ion Chemistry. The ranges and average values of major ion concentrations as determined from standpipe monitors are listed in Table 4-2. The standpipes are screened from 2.3 to 5.3 m below surface and therefore do not penetrate through the total thickness of the shallow overburden ground water zone. However, the average background quality in the upper 5 m (i.e. the most weathered zone) as determined from standpipes is considered most relevant for comparison to future ground water performance monitoring in the weathered zone.

4-13



A. - Sarnia site as Reported in Desaulniers (1980)



B. - Location 85-12

Figure 4-4

MAJOR ION CONCENTRATIONS OF GROUND WATER AT SARNIA, ONTARIO
COMPARED TO PREFERRED SITE

LEGEND

Weathered silt and clay

Unweathered silt and clay

Lower Till (Silt and sand till)

Bedrock

TABLE 4-2: MAJOR ION CONCENTRATIONS AND GENERAL CHEMISTRY OF GROUND WATERS AT THE PREFERRED SITE

PARAMETERS (all concentrations in mg/L unless otherwise noted)	SHALLOW OVERBURDEN GROUND WATER (BASED ON STANDPIPES) ¹		DEEP OVERBURDEN GROUND WATER (AT 25 M DEPTH)		BEDROCK GROUND WATER (UPPER 3 M) ²		ONTARIO DRINKING WATER OBJECTIVES
	RANGE OF VALUES	AVERAGE	RANGE OF VALUES	AVERAGE	RANGE OF VALUES	AVERAGE	
1. GENERAL CHEMICAL INDICATORS							
• pH (unitless)	6.9 to 7.4	7.1	8.0 to 8.6	8.2	7.3 to 7.7	7.4	-
• temperature (°C)	11 to 13	12	10 to 13	11	10 to 13	11	15*
• conductivity (umhos/cm)	6100 to 10000	8213	1110 to 1600	1365	2100 to 2660	2318	-
• total dissolved solids	8940 to 19600*	15255	806 to 1260	1041	2360 to 2960	1681	500*
• hardness ³ (as CaCO ₃)	5307 to 9742	7457	166 to 381	274	1034 to 1463	1280	500*
• dissolved inorganic carbon	110 to 210	167	6 to 17	13	16 to 26	21	-
2. MAJOR CATIONS							
• calcium (Ca)	335 to 434	398	42.3 to 92.9	68	325 to 382	353	-
• magnesium (Mg)	1090 to 2450	1575	14.7 to 37.3	25.4	96.5 to 124	110	-
• potassium (K)	5 to 11	8	<1 to 2	<1	<1 to 5	2.7	-
• silicon (Si)	5.86 to 7.81	6.72	3.21 to 4.02	3.49	3.60 to 4.63	4.04	-
• sodium (Na)	292 to 545	387	160 to 235	190	131 to 179	152	-
• strontium (Sr)	7.33 to 11.40	9.25	0.95 to 1.98	1.46	7.90 to 9.99	9.13	20*
3. MAJOR ANIONS							
• chloride (Cl)	7.3 to 18.2	11.6	18.8 to 37.3	27.9	28.7 to 49.9	41.4	250*
• fluoride (F)	4.68 to 7.60	6.27	0.83 to 1.18	0.97	2.14 to 2.73	2.37	2.4
• sulphate (SO ₄)	5280 to 8270	7353	400 to 760	588	1370 to 1650	1502	500*
• bicarbonate (HCO ₃) ⁵	793 to 880	785	44 to 69	57	63 to 111	85	-

1. Results from 85-10-10 not included because of surface water leakage into monitor.

2. Results from 85-1-1 not included because of possible dilution with drilling water.

3. Calculated from Ca and Mg using: total hardness = 2.5 Ca + 4.1 Mg (Freeze and Cherry, 1979, pg. 387).

4. Underlined concentrations exceed the Ontario Drinking Water Objectives.

5. Maximum desirable concentrations for parameters related to aesthetic quality.

6. Not an Ontario Drinking Water Objective, but levels in excess of this considered very poor for most domestic purposes due to incrustation and excessive soap consumption (Ontario Ministry of the Environment, 1983, pp. 40 to 41).

7. Not an Ontario Drinking Water Objective, but at levels above this, people on sodium restricted diets should consult their physician (Ontario Ministry of the Environment, 1983, pg. 28).

8. Maximum acceptable concentrations for parameters related to health.

9. Calculated from alkalinity.

The shallow overburden ground waters have neutral pHs in the range of 6.9 to 7.4. As previously indicated, they are characterized by very high concentrations of total dissolved solids (8940 to 19600 mg/L), sulphate (5280 to 9370 mg/L) and magnesium (1090 to 2450 mg/L), plus high concentrations of bicarbonate (753 to 880 mg/L), sodium (292 to 545 mg/L) and calcium (335 to 434 mg/L). Also present in significant concentrations are strontium (7.33 to 11.40 mg/L) and fluoride (4.68 to 7.60 mg/L). Potassium and chloride concentrations are low ranging from 5 to 11 mg/L and 7.3 to 18.2 mg/L respectively.

Although elevated levels of total dissolved solids, sulphate, bicarbonate, magnesium, calcium and sodium have been reported in the literature at several other clayey sites, most authors have not reported concentrations as high as those found at the Preferred Site (Table 4-3). Similar concentrations have been reported by Heystee et al. (1982) for one of two monitoring sites at the Lambton Generating Station. This generating station is located in a "waterlain" clayey till of the Lake St. Clair Clay Plain.

As evidenced by the range of major ion concentrations listed in Table 4-2, significant variation also occurs in the shallow overburden ground water quality between monitoring points at the Preferred Site. For most parameters, the maximum and minimum values vary by about a factor of 2. Considerable spatial variability has also been reported by Heystee et al. (1982), who reports differences in concentrations in piezometers at the same depths and in the same materials separated laterally by 30 m and 1.5 km.

The variations between values across the site and between others in Ontario are attributed to: (1) differences in the amount of weathering and/or fracturing, (2) variations in the

TABLE 4-3: COMPARISON OF MAXIMUM MAJOR ION CONCENTRATIONS OF GROUND WATERS WITHIN UPPER 9 M OF OVERBURDEN AT THE PREFERRED SITE COMPARED TO UPPER 9 M AT OTHER CLAYEY SITES IN ONTARIO

PARAMETERS (all in mg/L)	Preferred Site	Heystee et al.* (1982) Lambton, Ont. LGS-1	Heystee et al.* (1982) Lambton, Ont. LGS-2	Desaulniers (1980) Sarnia, Ont.	Desaulniers (1980) Mainfleet, Ont.	Desaulniers (1980) Wyoming, Ont.	Desaulniers (1980) Woodstock, Ont.
• Total Dissolved Solids	19600	NA	NA	2474	1406	1098	1729
• Calcium (Ca)	434	480	381	301	140	108	212
• Magnesium (Mg)	2450	1896	316	163	41	102	107
• Potassium (K)	11	23	11	12	2	4	5
• Silicon (Si)	7.81	NA	NA	NA	NA	NA	NA
• Sodium (Na)	545	575	207	191	218	85	230
• Strontium (Sr)	11.40	11	13	NA	NA	NA	NA
• Bicarbonate (HCO ₃)	880	1007	670	519	482	445	500
• Chloride (Cl)	18.2	354	35	89	35	35	393
• Sulphate (SO ₄)	9370	8165	2400	1355	548	355	624

NA = not analyzed

* Concentrations estimated from the Figures in Heystee et al (1982)

geochemical composition of the soil materials, (3) seasonal variations, and (4) variations in surface activities (such as plowing and type of crops). Because of the long screened interval of the standpipes (3m) variations between monitoring points at the Preferred Site may also be due to different proportions of ground water entering the monitors from various depths due to differences in the number and open nature of fractures encountered.

Major ion concentrations at any one monitoring point were reasonably consistent between the two sampling runs (June and late August/early September). However, since both of these runs were in the summer, these results cannot be used to establish if seasonal variations occur in the quality of the shallow overburden ground waters.

Minor Ions and Other Constituents. Ranges and average concentrations, as determined from the standpipes, are listed in Table 4-4. Also given are dissolved organic carbon and methane concentrations.

All minor ions were present at concentrations less than 1.1 mg/L. The minor ions present in highest concentrations were phosphorus (0.8 to 1.1 mg/L), boron (0.273 to 0.462 mg/L), iron (0.13 to 0.31 mg/L), chromium (<0.01 to 0.7 mg/L) and nickel (0.07 to 0.12 mg/L). The remaining minor ions were close to or below detection. The minor ions show considerably less spatial variation than the major ions.

Dissolved organic carbon concentrations were elevated, ranging from 18 to 99 mg/L with considerable spatial variations. The elevated concentrations are anomalous and considered to be the result of analytical error. Methane concentrations were low, ranging from 2.4 to 10.5 ppm by volume.

TABLE 4-4: MINOR ION CONCENTRATIONS OF GROUND WATERS AT THE PREFERRED SITE

PARAMETERS (all concentrations in mg/L unless otherwise noted)	SHALLOW OVERBURDEN GROUND WATER (BASED ON STANDPIPE ^{5,1})		DEEP OVERBURDEN GROUND WATER (AT 25 M DEPTH)		BEDROCK GROUND WATER (UPPER 3 M)		ONTARIO DRINKING WATER OBJECTIVES
	RANGE OF VALUES	AVERAGE	RANGE OF VALUES	AVERAGE	RANGE OF VALUES	AVERAGE	
1. MINOR CATIONS							
• Aluminum (Al)	-0.01 to 0.24	-0.05	-0.01 to 0.11	-0.04	-0.01 to 0.05	-0.01	-
• Barium (Ba)	-0.005 to 0.006	-0.005	0.008 to 0.014	0.012	-0.005 to 0.01	-0.007	1.0*
• Beryllium (Be)	-0.0005 to 0.0006	-0.0006	all - 0.0005	-0.0005	0.0005 to 0.005	-0.0005	-
• Boron (B)	0.273 to 0.462	0.363	0.352 to 0.428	0.373	0.441 to 0.525	0.466	5.0*
• Cadmium (Cd)	all	-0.01	all - 0.01	-0.01	all - 0.01	-0.01	0.005*
• Chromium (Cr)	-0.01 to 0.7	-0.18	-0.01 to 0.03	-0.02	0.04 to 0.06	0.05	0.05*
• Cobalt (Co)	-0.05 to 0.07	-0.05	all - 0.05	-0.05	all - 0.05	-0.05	-
• Copper (Cu)	-0.008 to 0.014	-0.009	all - 0.008	-0.008	all - 0.008	-0.008	-
• Iron (Fe)	0.13 to 0.31	0.18	0.02 to 0.05	0.03	0.17 to 0.38	0.21	1.0*
• Lead (Pb)	all	-0.05	all - 0.05	-0.05	all - 0.05	-0.05	0.3*
• Manganese (Mn)	-0.01 to 0.17	-0.03	0.02 to 0.04	0.03	0.02 to 0.04	0.03	0.05*
• Molybdenum (Mo)	-0.2 to 0.4	-0.2	-0.2 to 0.2	-0.2	-0.2 to 0.3	-0.2	0.05*
• Nickel (Ni)	0.07 to 0.12	0.10	all - 0.05	-0.05	-0.05 to 0.07	-0.06	-
• Phosphorous (P)	0.8 to 1.1	0.96	all - 0.5	-0.5	0.5 to 0.6	-0.5	-
• Silver (Ag)	-0.005 to 0.012	-0.005	all - 0.005	-0.005	-0.005 to 0.008	-0.005	0.05*
• Thorium (Th)	-0.05	-0.06	0.05 to 0.11	-0.07	-0.05 to 0.11	-0.06	-
• Titanium (Ti)	all	-0.005	all - 0.005	-0.005	all - 0.005	-0.005	-
• Vanadium (V)	-0.005 to 0.025	-0.007	-0.005 to 0.008	-0.006	-0.005 to 0.015	-0.009	-
• Zinc (Zn)	0.05 to 0.38	-0.09	-0.05 to 0.63	-0.19	-0.05 to 0.7	-0.18	5.0*
• Zirconium (Zr)	all	-0.05	all - 0.05	-0.05	all 0.05	-0.05	-
2. MINOR ANIONS							
• Bromine (Br)	all	-0.5	all - 0.5	-0.5	-0.5 to 0.7	-0.5	-
• Nitrite (NO ₂)	all	0.2	all - 0.2	-0.2	all - 0.2	-0.2	3.3*
• Nitrate (NO ₃)	-0.5 to 1.2	-0.6	-0.5 to 0.7	-0.5	all - 0.5	-0.5	44*
• Phosphate (PO ₄)	all	-10	all - 10	-10	all - 10	-10	-
• Sulphide (S)	-0.002 to 0.022	-0.005	-0.002 to 0.008	-0.005	-0.002 to 0.16	-0.03	0.05*
3. ORGANIC CONSTITUENTS							
• Dissolved organic carbon	18 to 99	44	6 to 30	19	4 to 55	19	5.0*
• Methane (ppm by volume)	2.4 to 10.5	4.8	63 to 311	182	69 to 540	205	3000*
• Volatile organic "priority pollutants"	-	-	-	-	-	-	0.005*
• Extractable organic "priority pollutants"	-	-	-	-	-	-	(benzene)

FOOTNOTES:

- Results from 85-10-10 not included because of surface water leakage into monitor, and results from June 17, 1986 sampling of 85-1-10 not included because of sediment in sample.
- Results from 85-1-1 not included because of possible dilution with drilling water.
- Underlined concentrations exceed the Drinking Water Objectives.
- Maximum acceptable concentrations for parameters related to health.
- Limit is for hexavalent chromium, whereas analysis was for total chromium.
- Maximum desirable concentrations for parameters related to aesthetic quality.
- Not an Ontario Drinking Water Objective. This is a federal drinking water objective from Environment Canada (1979), p.58.
- "priority pollutants" from the U.S. Environmental Protection Agency's list, excluding dioxins and dibenzofurans (see Table 3a, Appendix 3 for complete list of compounds and results). Scan was run on one sample only from 85-12-1.
- Not an Ontario Drinking Water Objective. This is the maximum concentration level proposed by the U.S. Environmental Protection Agency for drinking water.

Drinking Water Quality. Ground water in the overburden is not considered a significant resource because of the low permeability of the silt and clay materials. However, eleven shallow (generally <9 m) large diameter dug or bored wells were found to be in use in the site vicinity (see Section 5.3). These shallow wells generally supplement other sources of water supply and, for the most part, are used for domestic non-potable purposes (such as garden watering, laundry etc.). However, one dug well about 1 km west of the Preferred Site was reported as a sole source of domestic water supply. These wells were not sampled for chemical analysis.

Comparison of shallow overburden ground water quality in the standpipe monitors to the Ontario Drinking Water Objectives is given in Tables 4-2 and 4-4. The ground water is of poor quality with several parameters (mostly aesthetic) greatly exceeding the objectives. For parameters related to health, fluoride consistently exceeds the objectives by a factor of two to three. Sodium does not have an objective. However, at concentrations above 20 mg/L it is recommended that people on sodium restricted diets drinking the water consult with their physician (Ontario Ministry of the Environment, 1983). The shallow ground water consistently exceeds 20 mg/L of sodium by 15 to 27 times. For parameters related to aesthetic quality, total dissolved solids exceeds the objectives by 18 to 39 times, and hardness and sulphate exceed by 11 to 19 times. Iron and manganese exceeded the objectives in only a few instances. Dissolved organic carbon exceeds by 4 to 20 times but it is likely these elevated levels are due to analytical error.

Water quality in shallow wells around the Preferred Site should not however, be inferred from the quality in the

standpipe monitors. This is because these shallow water wells are likely susceptible to dilution from surface run-off and/or contamination from sources such as farm wastes, septic beds, etc. Background water quality in the shallow wells should be established by sampling individual wells.

Relationship to the Weathered Silt and Clay. The quality of the shallow overburden ground water is the result of weathering of the near surface silt and clay materials. From the twelve on-site boreholes logged in detail (Appendix C), the near surface silt and clay is heavily weathered to a depth of 1 to 2 m, with numerous fractures to 2 to 4 m. A colour change occurred from dark greyish brown to brown at depths ranging from 3.5 to 6.5 m. The weathered silt and clay is described in more detail in Section 2.3.2. The geochemical processes responsible for the shallow overburden ground water chemistry are considered to be similar to those discussed in Heystee et al. (1982) and in Freeze and Cherry (1979, pages 284 to 286).

Figures 4-2 and 4-3 show that the highest concentrations of total dissolved solids, sulphate and magnesium extend to approximately 7 or 8 m below grade. This is approximately 1 to 2 m below any visual evidence of weathering (as indicated by the colour change). However, at a downward ground water velocity of 4 mm/a, we might have expected these components to have migrated deeper than this in the 12,500 $\pm$ 500 years since glaciation ended. Ground water with elevated concentrations has likely penetrated only a few metres deeper than the zone of visual weathering because: (1) the depth to which weathering has extended and the amount of weathering has developed slowly over time since deposition of the sediment and (2) the main ions (Mg, Ca, Na, SO_4 and HCO_3) are potentially affected and retarded by geochemical processes.

As previously indicated, one possible explanation for the variation in shallow overburden ground water quality between monitoring points is variation in the amount of weathering and/or fracturing. Additional evidence for differential weathering is provided by comparing locations 85-1 and 85-12 where detailed information is available in the upper 8 m (Figures 4-2 and 4-3). Less weathering and/or fracturing of the near surface materials appears to have occurred at location 85-1. This is inferred by the lower concentrations of most constituents and the slower increases in concentration with depth at location 85-1. From the borehole logs (Appendix C1) soils at location 85-1 were found to be heavily weathered to only 0.6 m compared to 1 m at location 85-12, and numerous fractures were noted to only 2.2 m at location 85-1 compared to 5 m at location 85-12.

4.2.1.2 Deep overburden ground waters

Major ion chemistry. Below a depth of 9 m, concentrations of total dissolved solids, sulphate, bicarbonate, magnesium, calcium, sodium, strontium and fluoride, all rapidly decline within the first few metres and then continue to decline more slowly with increased depth. This trend is shown in Figures 4-2 and 4-3. Concentration ranges and average concentrations of the major ions at 25 m (the deepest overburden monitors) are listed in Table 4-2. At this depth the average concentrations of most constituents are 5 to 15 times lower than the average concentrations found in the shallow overburden ground water zone. Magnesium concentrations exhibit an even larger decrease, averaging about 60 times less. Sodium and silicon on the other hand, exhibit smaller decreases on the order of two times. Chloride concentrations follow an opposite trend, increasing slowly with depth, to approximately twice the concentration at 25 m.

Similar major ion trends have been noted at various sites in Ontario in clayey deposits by Heystee et al. (1982), Desaulniers (1980) and Desaulniers et al. (1981) (see Figure 4-4 for an example). However, after an initial decline in concentrations of TDS, SO_4 , Mg, Ca and Na with depth below the shallow overburden ground water zone, most of these sites exhibit a reversal to increasing concentrations with depth. This reversal occurs because the sites are underlain by very poor quality aquifers with ground waters much higher in chloride and sulphate than in the overlying overburden. Thus constituents are diffusing upward into the overburden at these sites, altering the chemistry of the deeper overburden ground waters. This does not occur to any appreciable extent at the Preferred Site because ground water in the bedrock below the site is of relatively similar quality to that in the deep overburden. Chloride concentrations in the bedrock are low and range from 28.7 to 49.9 mg/L compared to 18.8 to 37.3 mg/L in the deep overburden. Sulphate concentrations in the bedrock, although not low, range from 1370 to 1650 mg/L, compared to 400 to 760 mg/L at 25 m deep in the overburden.

Minor ions and other constituents. The ranges and average concentrations of minor ions from ground waters at 25 m are listed in Table 4-4. Also listed are the dissolved organic carbon and methane concentrations.

There is essentially no difference in the minor ion concentrations at 25 m than in the shallow overburden ground waters, except for chromium (9 x less) and iron (6 x less). Minor increases in barium and zinc and minor decreases in nickel and phosphorous were also noted.

Dissolved organic carbon concentrations decline slowly with depth but are still elevated at 25 m, ranging from 6 to 30 mg/L. The elevated concentrations are considered to be the result of analytical error.

Methane concentrations slowly increase with depth, until about 9 m. Between 9 and 15 m there is a more rapid increase. Below 15 m, methane increases are slow again. The maximum concentration detected at 25 m was 311 ppm by volume which is approximately 60 times greater than the average value in the shallow overburden ground water zone. The probable source of methane is upward diffusion from the bedrock ground waters where a maximum concentration of 540 ppm by volume was detected. A similar trend in methane concentrations with depth has also been reported by Heystee et al. (1982). The sharp shift in methane concentrations between 9 and 15 m is attributed by Heystee et al. (1982) to be the result of chemical and/or biological degradation of the methane diffusing from depth.

Drinking water quality. Ground water deep in the overburden is not a resource because of the very low permeability of the silt and clay materials. No wells obtain their water from the deep overburden ground water zone. Consequently comparison of this water quality to the Ontario Drinking Water Objectives is not warranted.

Indicators of solute diffusion. The trend of increasing chloride concentrations with depth reported by Heystee et al. (1982), Desaulniers (1980), Desaulniers et al. (1981) and Desaulniers et al. (1986) (see Figure 4-4 for an example) have been shown by these authors to be the result of upward diffusion from chloride rich bedrock waters. Diffusion occurred against

the direction of ground water flow at these sites because downward ground water velocities were very low (<5 mm/a). Downward ground water flow velocities are also very low at the Preferred Site (4 mm/a), therefore we would anticipate that upward diffusion of chloride might also occur at this site. Chloride concentrations are much lower at the Preferred Site than those reported at other sites but also show a trend of increasing concentration with depth through the overburden (Figures 4-2 and 4-3). However, these chloride profiles cannot be used to assess whether diffusion is a controlling solute transport mechanism at the Preferred Site as has been done at other sites. Figure 4-5 is a comparison of the chloride trend with depth at locations 85-8 and 85-12 versus that reported by Desaulniers (1980) for Wainfleet, Ontario where diffusion is taking place. Other sites reported in the literature show a similar trend to Wainfleet. This figure shows the trend is different at the Preferred Site. Upward diffusion results in more rapid concentration changes deep in the overburden than near surface. At the Preferred Site, however, the opposite trend is found. This likely occurs because of the much lower concentration gradients upward from the bedrock at the Preferred Site than at the sites published in the literature. Therefore it does not mean that diffusion is not a controlling solute transport mechanism, just that chloride cannot be used to assess this process at the Preferred Site.

The other constituents with higher concentrations in the bedrock than in the deep overburden at the Preferred Site (i.e. Ca, Mg, Sr, F and SO_4) are also not good indicators for assessing diffusion. This is because they are subject to geochemical reactions such as sorption, cation exchange and precipitation/dissolution.

The changes in major ion concentrations with depth at the Preferred Site (including chloride) are interpreted to be more

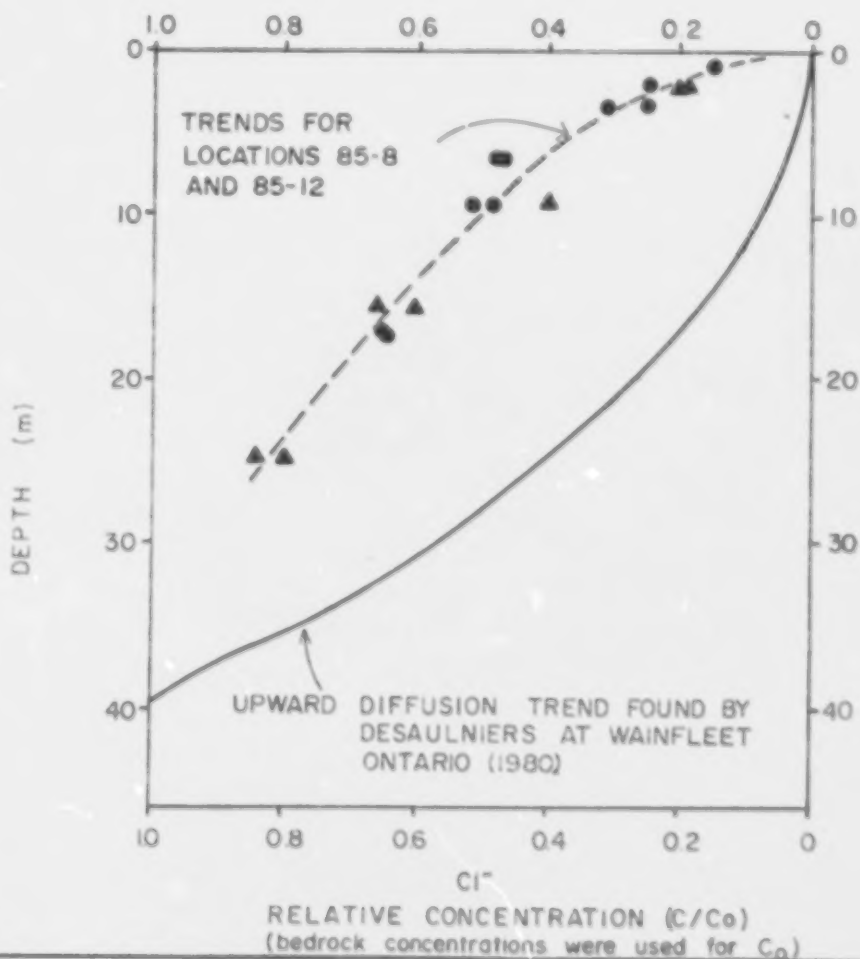
Figure 4-5.

COMPARISON OF CHLORIDE TRENDS WITH DEPTH
AT PREFERRED SITE AND WAINFLEET, ONTARIO

Legend

- ▲ Data from location 85-8
- Data from location 85-12

NOTE: data from 85-1 not shown because C_0 suspect due to possible dilution of bedrock water by drilling water



the result of slow downward movement and diffusion of dissolved constituents from the shallow overburden ground water zone mixing with the better quality, deep overburden ground waters; rather than upward diffusion from the bedrock. This is best illustrated in Figure 4-6. This figure is a trilinear plot showing the major ion chemistry of the shallow overburden ground water and deep overburden ground water at various depths. The cation composition of ground waters at intermediate depths between the standpipes (shallow overburden) and 25 m (deep overburden) lie approximately along a straight line in the direction of flow (downward). The anion compositions of all waters are too sulphate rich to show any trend. This trend, in the direction of ground water flow, infers that the intermediate ground waters are varying mixtures of the two types of ground water. This would also explain the chloride trend discussed above for the Preferred Site (Figure 4-6). If pore waters in the overburden at the time of deposition of the sediment were similar to the 30 to 40 mg/L range observed at the 25 m depth, subsequent downward flow and mixing of waters with lower chloride from the shallow subsurface would result in more rapid changes in chloride concentration with depth near surface than deeper in the overburden.

4.2.2 BEDROCK GROUND WATER CHEMISTRY

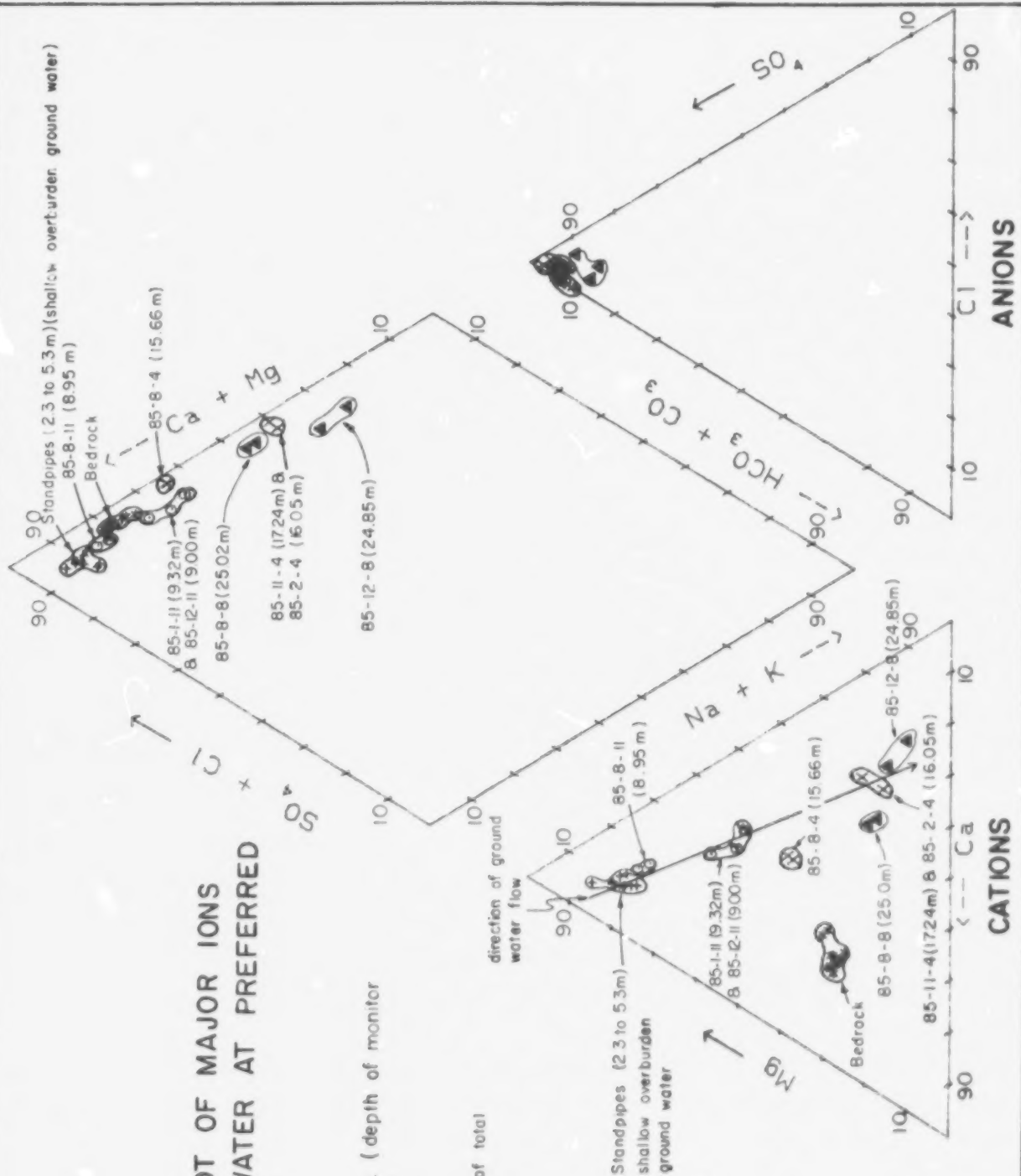
Ground water samples were collected on two occasions from five locations to characterize bedrock ground water chemistry (Figure 4-1). Bedrock monitors were screened over the upper 3 m of the rock. Based on Ontario Ministry of the Environment water well records (Appendix H1), and the water use survey (Section 5.0), almost all wells in the area obtain their water from this upper 3 m zone.

Figure 4-6
TRILINEAR PLOT OF MAJOR IONS
IN GROUND WATER AT PREFERRED
SITE

LEGEND

85-8-4 (15.66m) Monitor No. (depth of monitor in metres)

Data plotted as percent of total cation and anion meq/L



Major ion chemistry. Ranges of major ion concentrations and average concentrations are shown in Table 4-2. Results from monitor 85-1-1 have not been included because of suspected dilution with drilling water.

Bedrock ground water is cool (10 to 11°C.), and clear with almost neutral acidity (average pH of 7.4). The concentration of total dissolved solids averages 2681 mg/L. Sulphate is the main ion, with an average concentration of 1502 mg/L. Bicarbonate and chloride concentrations are quite low, averaging 85 and 41.4 mg/L respectively. The major cation is calcium, averaging 353 mg/L. Significant concentrations of magnesium and sodium are also present, averaging 110 and 152 mg/L respectively. Strontium and fluoride were found at concentrations higher than those normally present in potable ground waters. Strontium concentrations averaged 9.13 mg/L and fluoride concentrations averaged 2.37 mg/L.

As evidenced by the range of concentrations in Table 4-2, there is little spatial variability in the chemistry of the bedrock ground water. Temporal variations are not anticipated because of the isolation of bedrock ground waters from surface.

No published data are available on bedrock ground water chemistry in the vicinity of the Preferred Site for comparison to on-site chemistry.

Minor ions and other constituents. Ranges of minor ion concentrations and average concentrations are summarized in Table 4-4 along with concentrations of dissolved organic carbon and methane.

All minor ions were present at concentrations less than 1 mg/L. Those at highest concentrations were boron (0.441 to 0.525 mg/L), iron (0.17 to 0.38 mg/L) and zinc (<0.05 to 0.7 mg/L). Sulphide was also present at low but detectable concentrations in some monitors. A slight sulphurous smell was noted in bedrock ground waters at a few locations during drilling and also during monitor flushing. All other minor ions were close to or below detection. Similar to the major ions, the minor ions exhibit little spatial variation across the site.

Dissolved organic carbon concentrations were spatially variable and in most cases elevated, ranging from 4 to 55 mg/L. These elevated concentrations are likely the result of analytical error. Also present at significant concentrations and spatially variable was methane, ranging from 69 to 540 ppm by volume.

A scan for organic constituents on the U.S. Environmental Protection Agency's "priority pollutant" list was run on one sample of bedrock ground water from monitor 85-12-1 (Table 4-4). No "priority pollutants" were detected except very low levels of benzene. Detection limits for all components ranged from 0.001 to 0.01 mg/L. Benzene was found at a concentration of 0.002 mg/L.

Drinking water quality. As previously indicated, almost all wells in the Preferred Site area obtain their primary source of drinking water from the upper 3 m of bedrock. These wells were not sampled for chemical analysis. Comparison of the quality of bedrock ground water obtained from on-site monitors to the Ontario Drinking Water Objectives is given in Table 4-4.

Several parameters (mostly aesthetic) exceed the drinking water objectives.

For parameters related to health, fluoride exceeded the limits only slightly and on only 3 out of 8 analyses. Sodium does not have an objective. However, at concentrations above 20 mg/L it is recommended that people on sodium restricted diets consult their physician (Ontario Ministry of the Environment, 1983). Sodium concentrations in the bedrock ground water averaged 152 mg/L, about eight times higher than the 20 mg/L level. There is no Ontario Drinking Water Objective for benzene. However, the 0.002 mg/L detected is less than the maximum concentration level of 0.005 mg/L proposed by the U.S. Environmental Protection Agency.

For parameters related to aesthetic quality, total dissolved solids consistently exceed the objectives by about five times. Hardness and sulphate exceed by about three times. Dissolved organic carbon exceeds by a factor of 3 to 11, however these elevated levels are likely the result of analytical error. Iron slightly exceeds the objective in only one out of eight analyses. There is no Ontario objective for sulphide. However, a limit of 0.05 mg/L has been recommended by Environment Canada (1979). Only one out of eight analyses exceeded this value.

Relationship to ground water flow. No significant changes in concentration or the nature of chemical constituents were noted along the direction of lateral ground water flow in the bedrock (from north to south.).

Figure 4-6 shows the bedrock major ion chemistry plotted on a trilinear diagram. The cationic composition of the bedrock

ground water does not plot along the same linear trend as the overburden ground waters. This infers that the ground water within the bedrock is not recharged solely by downward ground water flow out of the overburden. This is also supported by the oxygen-18 and deuterium contents, which are more positive in the bedrock than in the overlying overburden. Isotopic results are discussed in more detail in Section 4.3. Bedrock ground water chemistry is likely a mixture of overburden ground water and lateral flow in the bedrock from upgradient recharge areas. The relative amounts of ground water contributed through the overburden versus upgradient flow in the bedrock cannot be determined from the chemistry data.

4.3 ENVIRONMENTAL ISOTOPES

4.3.1 INTRODUCTION

This section describes and interprets the ground water isotope results. The isotopes analyzed were tritium, oxygen-18, deuterium and carbon-14.

Tritium is an indicator of ground waters recharged since the early 1950's. Given the slow downward ground water velocities (4 mm/a), ground waters throughout most of the overburden at the Preferred Site should have originated long before the 1950's and therefore not contain detectable levels of tritium. Tritium samples were collected to confirm this. The exception is in the near surface, where fracturing and weathering has enhanced the permeability and resulted in a shallow zone of more active ground water recharge and flow that should contain tritium. Tritium samples were collected to assist in interpreting the depth of this active shallow ground water flow system. The tritium results are discussed in Section 4.3.2.

Oxygen-18 (^{18}O) and deuterium (^2H) contents of the ground waters were determined to confirm that ground water velocities are very slow. If we consider the average downward ground water velocity (4 mm/a) and average thickness of unweathered overburden (28 m) at the Preferred Site, ground waters near the base of the overburden should be several thousands of years old. Cold, glacial pore waters have ^{18}O and ^2H contents considerably more negative than the more temperate waters which began recharging when the climate warmed a few thousand years after glaciation ended. If ground water flow is as slow as velocity calculations indicate, then ^{18}O and ^2H contents of ground waters near the base of the overburden at the Preferred Site should still retain some of their glacial character and therefore be more negative than values for more recent temperate precipitation. The ^{18}O and ^2H results are discussed in Section 4.3.3.

For additional confirmation that ground waters deep in the overburden are old, two samples of ground water were collected for carbon-14 dating. These results are discussed in Section 4.3.4.

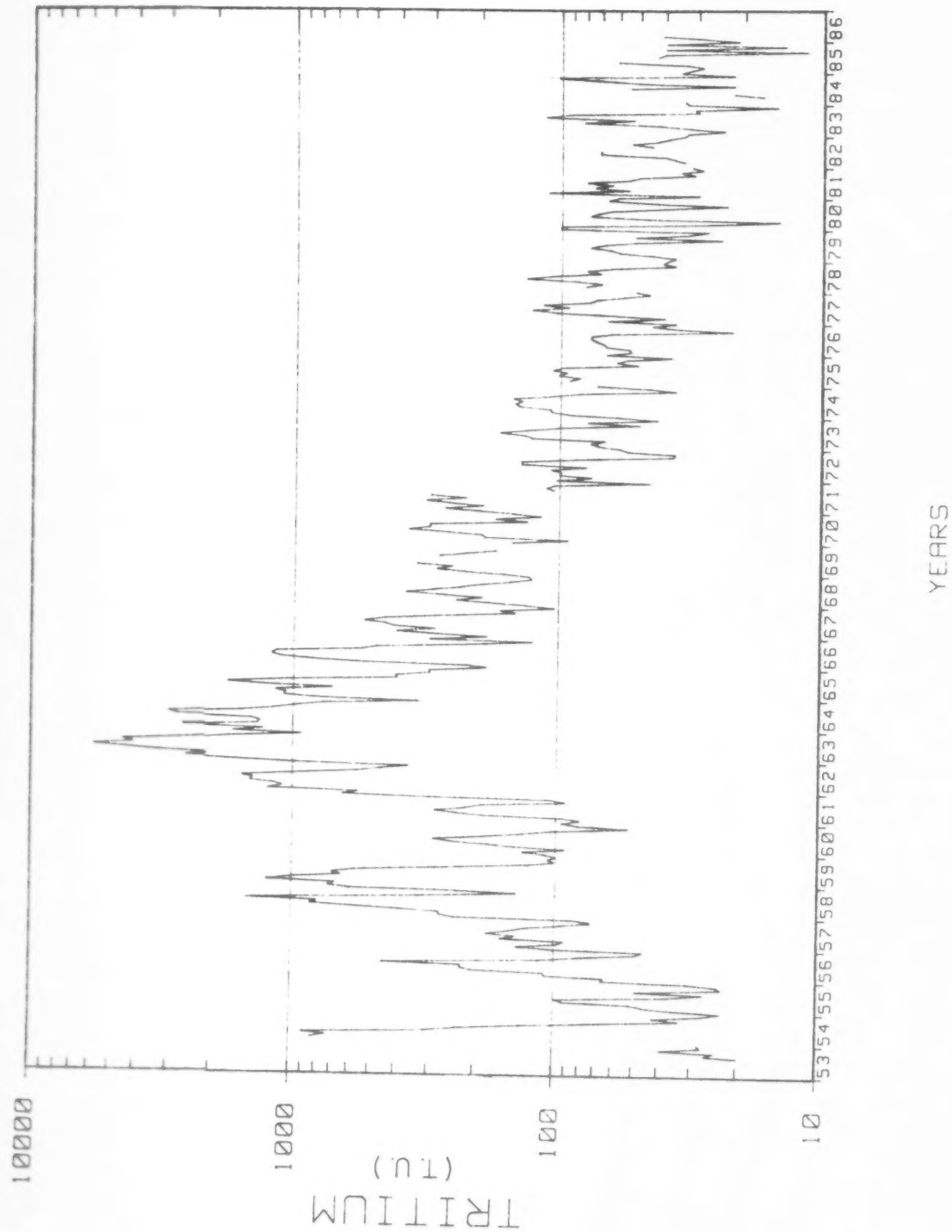
4.3.2 TRITIUM

4.3.2.1 General principles

Tritium (^3H) is a radioactive isotope of hydrogen with a half life of 12.3 years. Tritium is measured in tritium units (T.U.), where 1 T.U. equals 1 tritium atom in 10^{10} hydrogen atoms. Following 1953, tritium levels in precipitation increased dramatically as a result of above-ground testing of thermonuclear bombs. Figure 4-7 shows tritium concentrations in precipitation at Ottawa, Ontario, where monthly measurements have been made since late 1953. The results from Ottawa are considered to be representative of precipitation falling on the

Figure 4-7

VARIATIONS OF TRITIUM IN PRECIPITATION (MEAN MONTHLY CONCENTRATIONS) AT OTTAWA, ONTARIO



Preferred Site. Through the 1950's and 1960's tritium levels reached thousands of T.U.'s. Levels have been declining slowly since 1964 following a ban on atmospheric testing of thermonuclear devices. In 1985 the levels in precipitation from Ottawa ranged from 12 to 61 T.U. In contrast, pre-1953 levels of tritium in precipitation have been estimated to range from 5 to 20 T.U. (Freeze and Cherry, 1979).

Tritium concentrations in ground water are not appreciably affected by interactions with geologic materials (Desaulniers et al, 1981). Consequently, considering the time elapsed since the early 1950's, and the half life of tritium, groundwaters recharged by pre-1953 precipitation with tritium of 20 T.U.'s now will have tritium levels below about 3 T.U. Detection of tritium above these levels indicates that part or all of the ground water recharged since 1953.

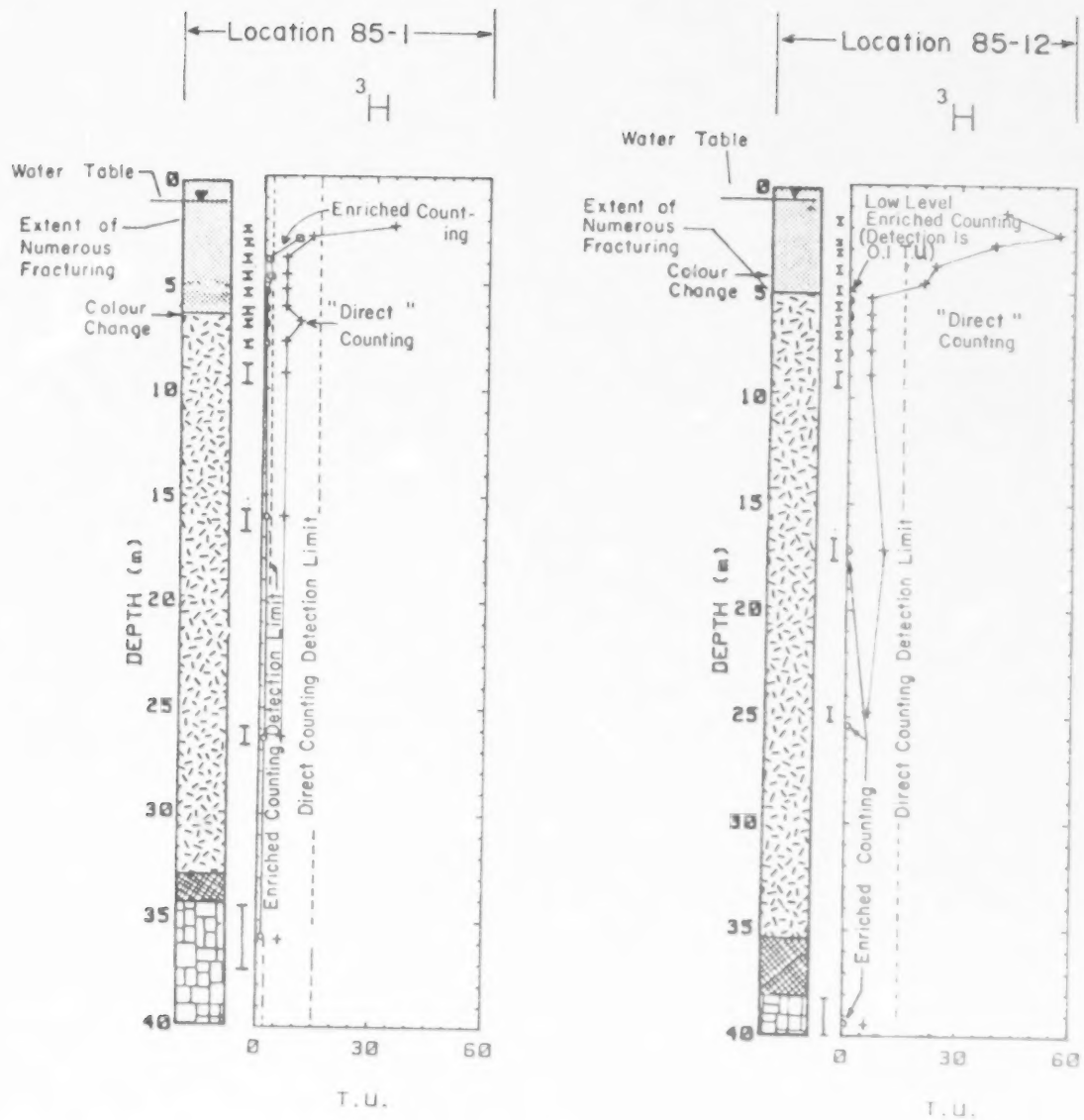
4.3.2.2 Tritium results

All ground water monitors (Figure 4-1) were sampled and analyzed at least once for direct counting of tritium (detection limit of 6 ± 8 T.U.). Monitors with tritium concentrations below detection were sampled again and analyzed for enriched counting of tritium (detection limit of 0.8 ± 0.8 T.U.). Four monitors at location 85-12 ranging in depth from 5.3 to 7.9 m, were also sampled and analyzed for enriched counting of low level activity tritium (detection limit 0.1 ± 0.1 T.U.). Tritium results are tabulated in Appendix J.

Tritium was not detected above 3 T.U. in any monitors below 5 m, including bedrock. This confirms that ground waters below 5 m in the overburden and ground waters in the bedrock recharged some time before 1953.

Detailed profiles of tritium concentrations with depth were determined in the upper several metres at locations 85-1 and 85-12. The results are shown in Figures 4-8. Tritium concentrations at both sites were generally highest near the water table and decreased with depth. At location 85-12 tritium was detected above 3 T.U.'s down to and including the monitors screened from 4.5 to 4.8 m, but not the monitor screened from 5.2 to 5.5 m. The tritium concentration in this latter monitor was only 0.25 ± 0.1 T.U.'s. Deeper monitors had even less tritium, being near or below detection (low level enriched counting). At location 85-1, tritium was detected above 3 T.U.'s only down to approximately 3.5 m. Deeper monitors had tritium levels below detection (enriched counting). This implies that the zone of recent recharge and "active" ground water flow in the shallow subsurface due to fracturing does not extend below about 5 m, and at location 85-1 may only be about 3.5 m deep. This is consistent with the ground water modelling results presented in Section 3.5.2 that imply the zone of most active flow may extend to about 3.5 m.

Although the general trends of tritium are the same at locations 85-1 and 85-12, the magnitude of concentrations and depth of penetration are significantly different (Figure 4-8). At location 85-1 tritium concentrations ranged from 35 ± 7 T.U. at the water table to 1.6 ± 0.8 T.U. at 3.7 m. At location 85-12 tritium concentrations ranged from a maximum of 56 ± 7 T.U. about 1 m below the water table to 20 ± 7 T.U. at 4.8 m. As was inferred by the shallow ground water chemistry at these locations (Section 4.2.1.1), the differences in tritium results between the two locations likely reflect a greater amount of fracturing and "active" ground water flow in the shallow subsurface at location 85-12 than at location 85-1.



NOTE:

1. Direct Counting Detection Limit is set at 14 T.U. because lowest reportable values are 628 T.U.
2. Enriched Counting Detection Limit is set at 1.6 T.U. because reportable values are 0.8±0.8 T.U.

Figure 4-8

TRITIUM CONCENTRATIONS IN GROUND WATER
AT LOCATIONS 85-1 and 85-12

Weathered silt and clay

Unweathered silt and clay

Dolostone bedrock

Lower Till (Silt and sand fill)

4.3.3 OXYGEN-18 AND DEUTERIUM

4.3.3.1 General principles

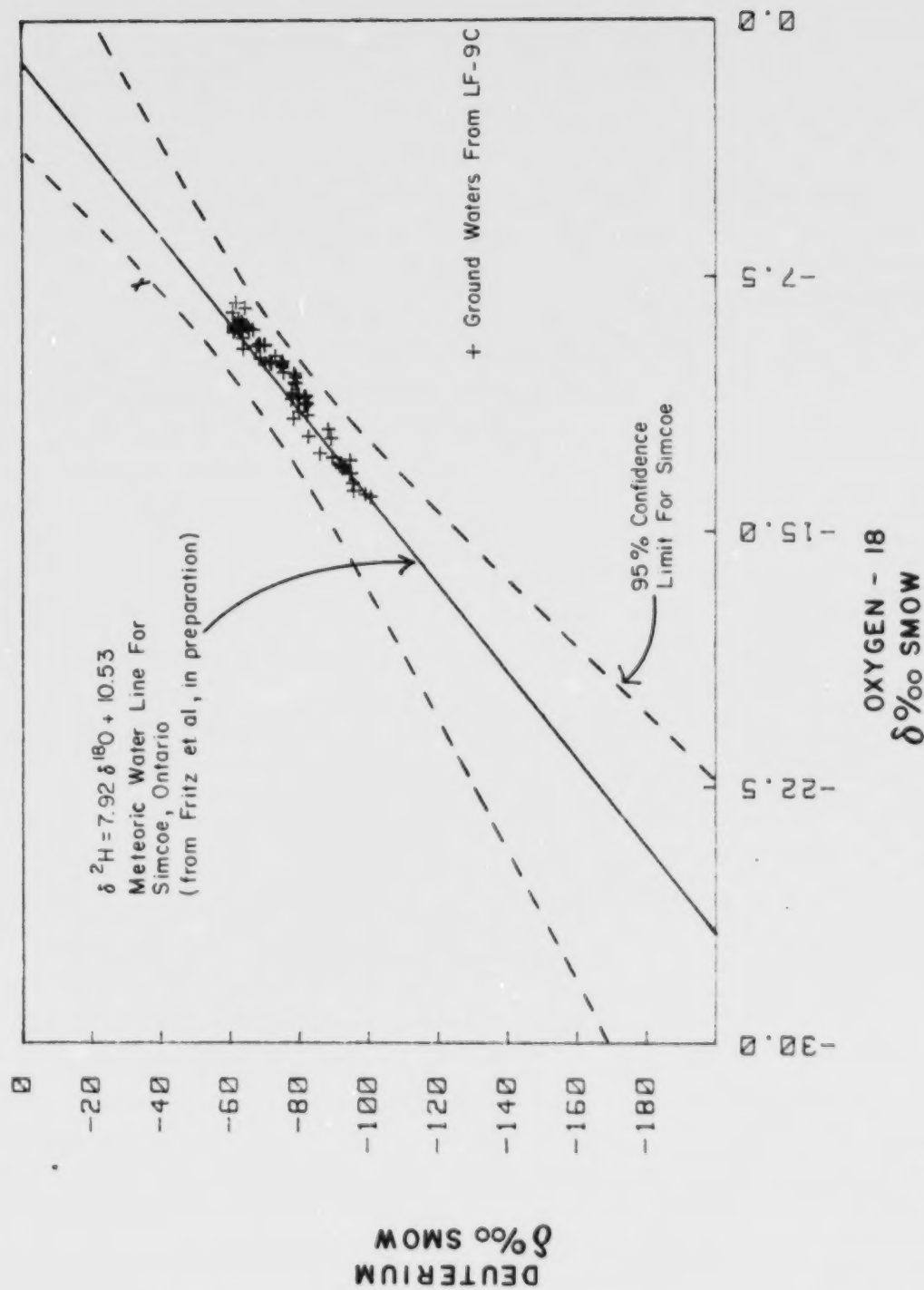
Oxygen-18 (^{18}O) is a naturally occurring stable isotope of oxygen. Oxygen most commonly exists as ^{16}O . The relative abundance of ^{18}O and ^{16}O are 0.20% and 99.76% respectively (Montgomery and Perry, 1982). Deuterium (^2H) is a naturally occurring stable isotope of hydrogen. Hydrogen most commonly exists as ^1H . The relative abundance of ^2H and ^1H are 0.016% and 99.98% respectively (Montgomery and Perry, 1982).

Isotopic compositions of ^{18}O and ^2H are expressed in the standard $\delta^0/00$ format. This is the difference (δ) in isotopic ratios ($^{18}\text{O}/^{16}\text{O}$ and $^2\text{H}/^1\text{H}$) of the sample, in parts per thousand (expressed as $^0/00$), with respect to a standard. The standard used for ^{18}O and ^2H is Standard Mean Ocean Water (SMOW). Therefore if a water sample contains less ^{18}O or ^2H than the standard, it will have a negative δ value. Ground waters generally have negative δ values.

Oxygen-18 and deuterium levels in ground water are generally not affected by interactions with geologic materials at low temperatures (Desaulniers et al. 1981). As a result, ^{18}O and ^2H contents in ground water closely approximate those in the precipitation from which they were recharged. When the ^{18}O contents of precipitation from a particular meteorological system are plotted versus the ^2H contents, they generally form a straight line. This line is referred to as the meteoric water line. If interactions during infiltration or in the subsurface alters the ^{18}O or ^2H contents a characteristic shift from this line will occur. Figure 4-9 shows the meteoric water line, with 95% confidence limits, for Simcoe, Ontario, 14 km SE of the Preferred Site (Fritz et al., in prep.). This line is considered

Figure 4-9

COMPARISON OF ^{18}O AND ^2H CONTENTS IN GROUND WATERS AT PREFERRED SITE TO METEORIC WATER LINE FROM SIMCOE, ONTARIO



representative of precipitation throughout most of southern Ontario. Also plotted on Figure 4-9 are all ground waters from the Preferred Site. All of the ground waters plot along the meteoric water line, well within the 95% confidence limits. This indicates that the ^{18}O and ^2H contents of ground waters at the Preferred Site have not been altered by geochemical interactions.

4.3.3.2 Oxygen-18 and Deuterium profiles through the overburden

Naturally occurring changes in ^{18}O contents with depth in the overburden have been investigated in ground waters at several sites in Ontario by Heystee et al. (1982), Desaulniers et al. (1982, 1981) and Desaulniers (1980). These studies found the ^{18}O contents to decrease (become more negative) regularly with depth. An example is given in Figure 4-10 from Desaulniers (1980) for Wainfleet, Ontario (14 km SE of the Preferred Site). Oxygen-18 contents at the water table were typical of present day, temperate precipitation (approximately -10‰), and those deep in the overburden (~ 30 m) were typical of colder, glacial pore waters (about 15‰). From these results, Desaulniers concluded that downward ground water flow was so slow that the ground waters at depth were still characteristic of those present in the sediments at the end of glaciation approximately 10,000 to 15,000 years ago. By comparing the field data to a one dimensional solute transport model (Figure 4-11), the trends in ^{18}O at Wainfleet were shown by Desaulniers (1980) to result from approximately 10,000 to 15,000 years of downward ^{18}O movement by very slow downward ground water flow and solute diffusion. The results from the Wainfleet site are representative of those reported in the literature for other sites in Ontario.

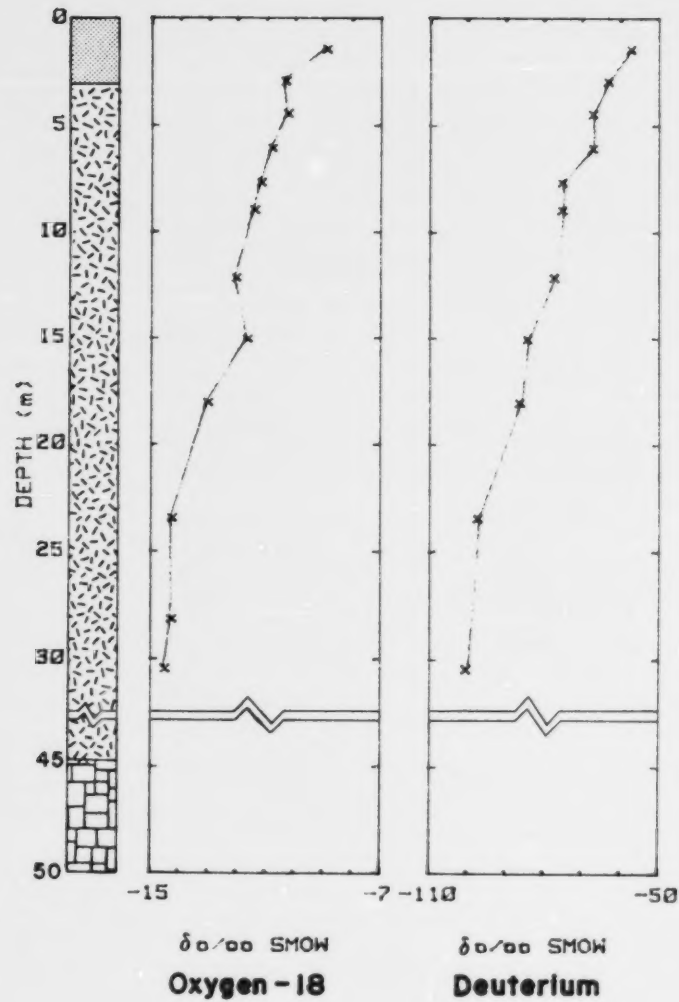


Figure 4-10

OXYGEN-18 AND DEUTERIUM CONTENTS OF
GROUND WATERS AT WAINFLEET, ONTARIO
(data from Desunlniers, 1980)

Weathered silt and clay Unweathered silt and clay

Bedrock

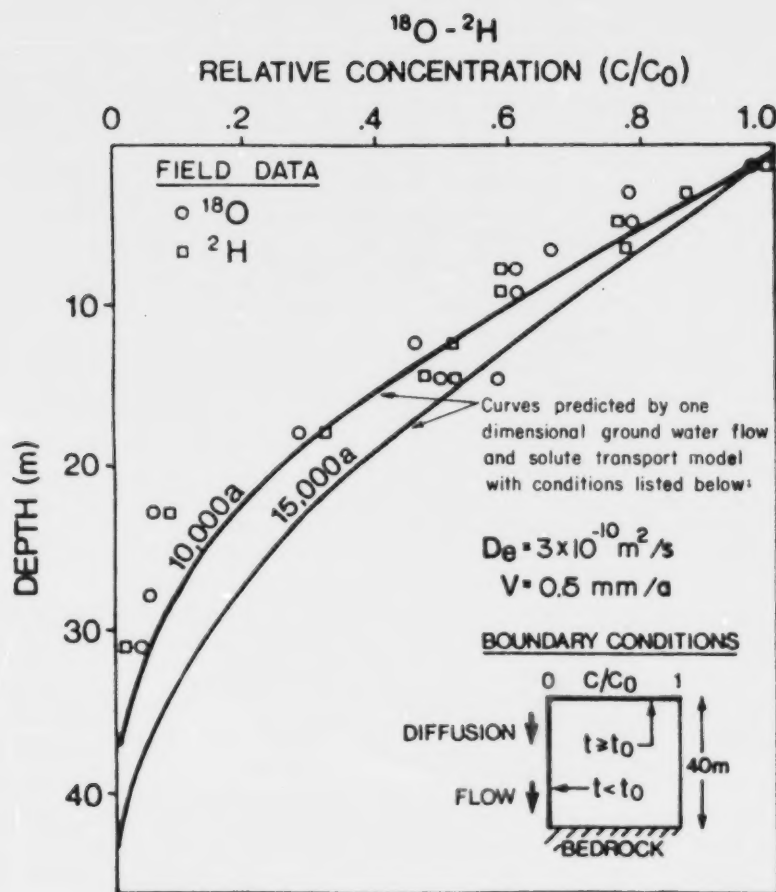


Figure 4-11

COMPARISON OF MEASURED ^{18}O AND ^2H CONTENTS
WITH TREND SIMULATED BY SOLUTE TRANSPORT MODEL
FOR WAINFLEET, ONTARIO (modified from Desaulniers, 1980)

Deuterium contents were also investigated in some of the published studies, and were found to follow the same trends as ^{18}O (see Figure 4-10 and 4-11 for Wainfleet). This is as expected since ^{18}O and ^2H contents are linearly related via the meteoric waterline (Figure 4-9).

The ^{18}O and ^2H contents of ground waters with depth at the Preferred Site, from locations 85-1 and 85-12, are shown in Figure 4-12. Oxygen-18 and deuterium contents were analyzed in both ground water samples from piezometers and in pore waters squeezed from soil samples. The piezometer and pore water squeezing results compare favourably. Figure 4-12 also shows the data from Wainfleet, Ontario, as reported in Desaulniers (1980), for comparison to the trends at the Preferred Site.

There are three main points to note about the ^{18}O and ^2H trends of Figure 4-12. These are as follows.

- (1) The trends of ^{18}O and ^2H with depth at the Preferred Site are very similar to those reported in the literature for other clayey silts in Ontario (i.e. ^{18}O and ^2H contents decrease (become more negative) with depth from values typical of modern, temperate precipitation (-8.26 to -9.12 ‰ for ^{18}O and -60.9 to 61.8 ‰ for ^2H at the Preferred Site) to values typical of colder waters near the base of the overburden (-13.99 ‰ for ^{18}O and -100.9 ‰ for ^2H at 34 m in location 85-12).
- (2) The most negative ^{18}O and ^2H values found near the base of the overburden at the Preferred Site (-13.99 ‰ and -100.9 ‰ respectively) are slightly more positive than those reported in the literature for other sites in Ontario, which range from -15 to -17 ‰ for ^{18}O and -100 to -120 ‰ for ^2H .

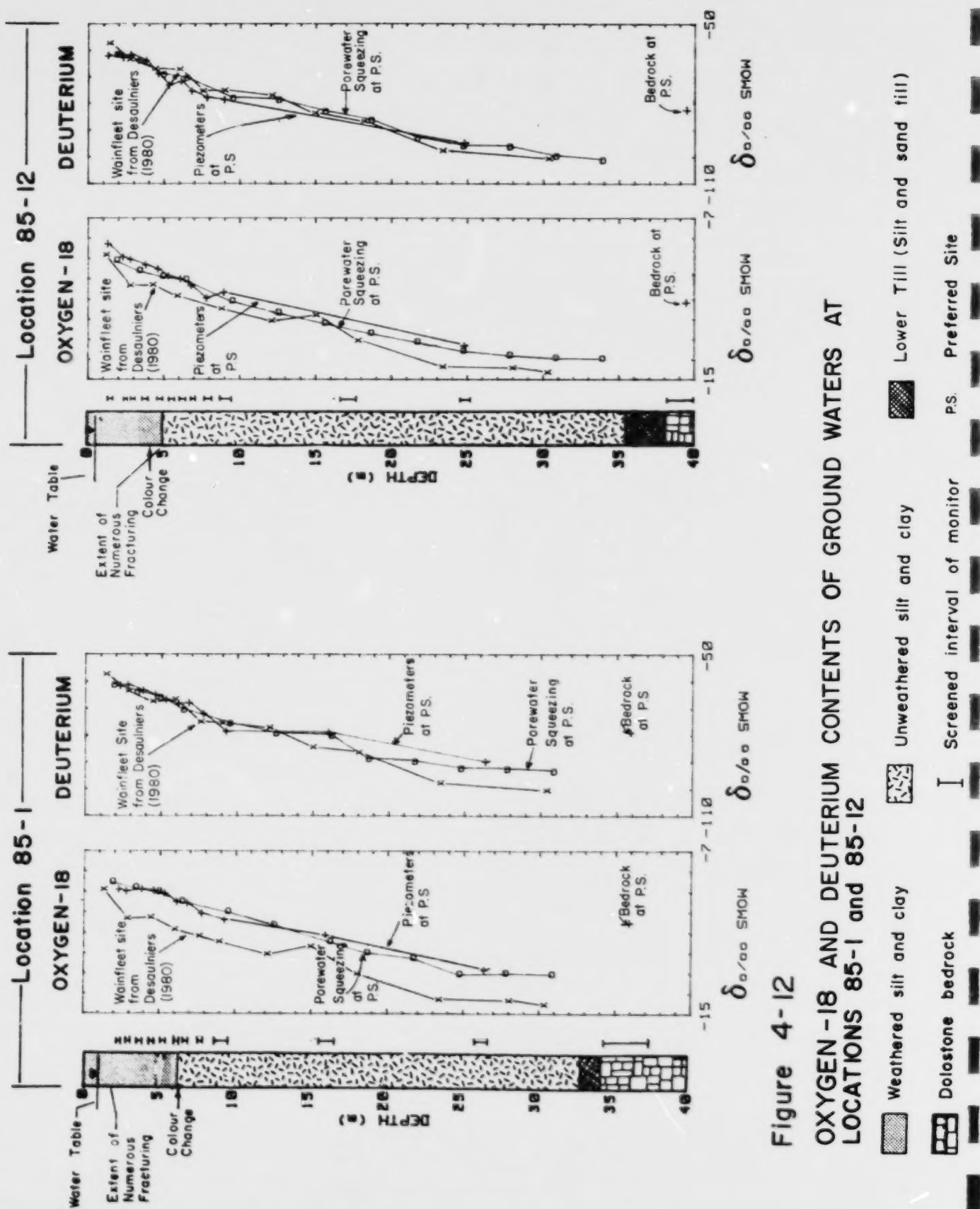


Figure 4-12

OXYGEN-18 AND DEUTERIUM CONTENTS OF GROUND WATERS AT
LOCATIONS 85-1 and 85-12

- (3) Oxygen-18 and ^2H values in the bedrock ground waters at the Preferred Site are more positive than those in the ground waters at the base of the overlying overburden. At location 85-12 for example, the bedrock values are -11.26 for ^{18}O and -82.3 $^{\circ}$ /oo for ^2H compared to -13.99 $^{\circ}$ /oo and -100.9 $^{\circ}$ /oo for ^{18}O and ^2H respectively at 34 m deep in the overburden.

At the end of glaciation, pore waters in glacial sediments had ^{18}O contents equal to or more negative than -15 $^{\circ}$ /oo (Quigley and Crooks, 1983). The glaciers retreated from the vicinity of the Preferred Site approximately 12,500 years ago (Feenstra, 1981 and Calkin and Feenstra, 1985). Following glaciation, the climate warmed until temperatures similar to today were reached, approximately 8000 $\pm$ 500 to 10000 $\pm$ 500 years ago (Edwards, pers. comm.). Since this time, temperatures have remained relatively constant (Edwards, pers. comm.). Modern temperate precipitation in the vicinity of the Preferred Site, based on data from Simcoe, Ontario (Fritz et al. in prep.) has an average ^{18}O content of -9.9 $^{\circ}$ /oo. This is likely typical of the waters that have been recharging for the last 8000 to 10000 years. Ground waters at a depth of 31 to 34 m in the overburden at the Preferred Site, however, have ^{18}O contents in the range of -13 to -14 $^{\circ}$ /oo. This indicates that downward ground water flow and solute transport at the Preferred Site is very slow, since ground waters deep in the overburden still retain part of their glacial isotopic composition despite about 8000 to 10000 years of recharge at surface by isotopically heavier waters.

The slightly more positive ^{18}O (and ^2H) values found at depth in the overburden at the Preferred Site compared to those

reported for other sites in Ontario may result because the downward ground water velocity at the Preferred Site is slightly higher than at the other sites. For example, the average velocities at the four sites studied by Desaulniers et al. (1981) range from 1.3 to 2.6 mm/a compared with 3.8 mm/a at the Preferred Site.

The more positive values may also be the result of upward diffusion from the bedrock. As previously indicated, bedrock ground waters have more positive ^{18}O and ^2H contents than the overlying overburden. The origin of the bedrock values is not known at this time. However, for the very slow ground water velocities measured in the overburden, diffusion upward against ground water flow is possible.

The more positive ^{18}O and ^2H values in the bedrock, also support the major ion chemistry results and ground water flow results, suggesting that bedrock ground waters are not solely recharged by downward ground water flow through the overburden, but also include some component of flow from upgradient areas.

4.3.4 RADIOCARBON DATING

As additional confirmation that ground waters near the base of the overburden are old, two samples were collected from monitors 85-8-8 and 85-12-8 at 25 m for carbon-14 dating. The results of this sampling are inconclusive because of sample contamination with modern atmospheric carbon (as CO_2). Resampling of these monitors is recommended.

5-1

5.0 GROUND WATER USE

5.0 GROUND WATER USETABLE OF CONTENTS

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5.0 GROUND WATER USE

5.1 INTRODUCTION

5.1.1 PURPOSE AND SCOPE

The sources of water supplies for domestic, livestock and general agricultural purposes in the vicinity of the Preferred Site are described in this section.

The vicinity of the Preferred Site is not serviced by a regional or municipal treated water supply system. Most residences and farming operations rely on individual water supply systems which may use ground water, rain water, pond water, creek water, bottled or purchased water, or any combination of these, as a source of supply. Although this study focuses on ground water as a source of supply, other sources are briefly described in order to place ground water usage in the context of total water usage in the vicinity of the Preferred Site.

A discussion of the regional hydrogeology as it relates to major sources of ground water supply is presented in Section 5.2. The characteristics of the local ground water resource are described in Section 5.3. Local sources of supply are discussed in Section 5.4. The quantity of water used from identified sources is discussed in Section 5.5. Potential (future) uses are briefly discussed in Section 5.6.

5.1.2 BACKGROUND

Water use in the vicinity of the Preferred Site was determined as part of the Phase 4A studies and is documented in the "Technical Appendix" (GLAL, 1985). The Phase 4A study utilized water well records supplied by the Ministry of the Environment

and water use information obtained during a house-to-house survey which included residents and landowners on the site and on adjacent properties. A total of 17 residents provided water use information. The information is summarized in Table 6 of the "Technical Appendix" LF-9C (GLAL, 1985) and copies of the actual interview forms are on file with the Ontario Waste Management Corporation.

The Phase 4B water use investigation builds on the results of the Phase 4A study.

5.1.3 METHODOLOGY

The Phase 4B investigation of water use covered an expanded study area from that surveyed in Phase 4A and involved the collection of more detailed water use information. The study area included the site and the adjacent area as shown in Figure 5-1 (back pocket). Since residences are generally located along concession roads, the study area was extended to encompass adjacent concession roads where they are present such as to the north and east.

To the south, the study area was enlarged to include all properties between the Preferred Site and the Welland River. These properties are downgradient from the site along the principal direction of ground water and surface water movement. Based on the assessment of ground water flow directions presented in Section 3.3, any contaminant movement from the site, through the bedrock aquifer, would be southerly towards the Welland River.

Information on springs and flowing wells located immediately beyond the study area has been included where identi-

fied by local residents. These features are not common in the area and their presence warranted identification.

Water use information used in this investigation consists of water well records supplied by the Ontario Ministry of the Environment and data obtained from landowners, tenants, and in some cases, previous landowners of properties within the study area. Water well records for the Phase 4A study were reviewed and additional well records were obtained from the Ministry of the Environment to provide complete coverage of the larger study area. Information provided in the water well records is summarized in Table H1-1, Appendix H1.

Water use information was obtained during a house-to-house survey of the study area. A copy of the survey form is presented in Appendix H2. The field data were collected by the same person (a GLL hydrogeologist) who visited all properties within the study area. This insured uniformity in the information obtained during the interviews.

The house-to-house survey of water use was completed in late August and early September, 1986. Information, collected at this time, included:

- name, ownership or tenant status, interview and assessment role numbers, location;
- water use information including source, quantity and quality of supply,
- wells and cistern construction details;
- storage tanks, treatment and problems with supply;
- characteristics of on-site surface water; and
- location of oil and gas wells.

No water samples for chemical analyses were collected during the survey. However, as part of the survey, the residents were asked whether a sample could be collected from their well(s) in the future. Domestic wells may be included as part of an area wide monitoring system.

A total of 115 separate parcels of land lie within the study area. The locations of the parcels, which are identified by an assessment roll number, are shown in Figure 5-1 (in map pocket). Field information was obtained for 112 parcels of land. In three instances, the interviewed owner declined comment. In these cases information collected from other sources including the Phase 4A study, as well as information provided by neighbors was used.

A separate survey form was completed for each water well located on the same property. Water use information collected during the survey is summarized in Table H2-1, Appendix H2. Locations of wells, cisterns, springs and ponds are also shown in Figure 5-1 (in map pocket).

Surface water information collected during the survey was provided to the surface water consultant, M.M. Dillon, for inclusion in their report describing surface water use (M.M. Dillon, 1987). It should be noted that the study area for the surface water survey varied from that for the ground water survey in that it followed stream courses.

Existing oil and/or gas wells were identified as part of the water use study. Existing well records were obtained from the Petroleum Resources Section of the Ministry of Natural Resources and additional data were collected during the field survey. The oil and gas well data are summarized in Table C3-1, Appendix C3. The well locations are included in Figure 5-1.

5.2 REGIONAL GROUND WATER RESOURCES

Information on ground water use in the central portion of the Niagara Peninsula is provided in GLAL (1984a and 1985), Turner (1978), Mellary and Aaltonen (1973) and Sibul et al. (1980). Unpublished site specific investigations and drilling programs undertaken by GLAL have also contributed to the discussion of regional ground water use provided below.

5.2.1 OVERBURDEN

For the most part, the overburden in the central portion of the Niagara Peninsula consists of fine textured materials. Ground water is expected to move very slowly through these materials as a result of their low hydraulic conductivity. Wells developed in these materials are generally shallow, large in diameter and are sustained by seepage from coarser laminations and any fractures which may be present. Yields are considered to be relatively low and peak use is likely accommodated by storage.

Granular materials, occur locally in the central portion of the Niagara Peninsula, as either discrete lenses or layers interbedded within the glaciolacustrine and till materials (located primarily along moraines such as Niagara Falls about 5 km north of the Preferred Site or Vinemount moraines about 10 km north of the Preferred Site) or as a thick deposit of granular material (Fonthill Kame Delta, Fonthill area about 6 km east of the Preferred Site).

Along the moraines, the granular materials are generally thin and of limited geographic extent. The few water wells which are completed in the granular are generally low-yielding and not capable of high sustained well yields. Many water wells in these areas are completed in the underlying bedrock because of the low productivity of the overburden.

The Fonthill Kame Delta deposit is capable of yielding water supplies above normal domestic requirements. The well yield is dependent upon local permeability and thickness characteristics of this deposit. The Town of Pelham (about 10 km east of the Preferred Site) obtains water from two wells constructed in the sand and gravel of the Fonthill Kame-Delta. These wells are 14.6 m and 14.0 m deep, respectively.

Water quality is expected to vary in the overburden. Quality is generally good where granular material occurs at or near surface and the ground water is readily recharged by precipitation. Quality is often poor in fine textured materials due to the slow ground water flow rates.

Information on the water quality of the overburden at the Preferred Site is provided in Section 4.2.

5.2.2 BEDROCK

The underlying bedrock in the central portion of the Niagara Peninsula is comprised of three bedrock formations, which from north to south are the Lockport-Amabel, Guelph and Salina Formation. The distribution of the bedrock formations are shown in Figure 5-2.

The Guelph Formation which underlies the Preferred Site and the Lockport-Amabel Formation located north of the Preferred Site, form the most significant bedrock aquifer in this area. Highly productive areas of this aquifer as outlined by Turner (1978), are shown in Figure 5-2. The permeability of the aquifer is due primarily to the fracturing and chemical dissolution of the upper portion of the bedrock. Most water wells obtain adequate supplies within the upper 3 m of the bedrock.

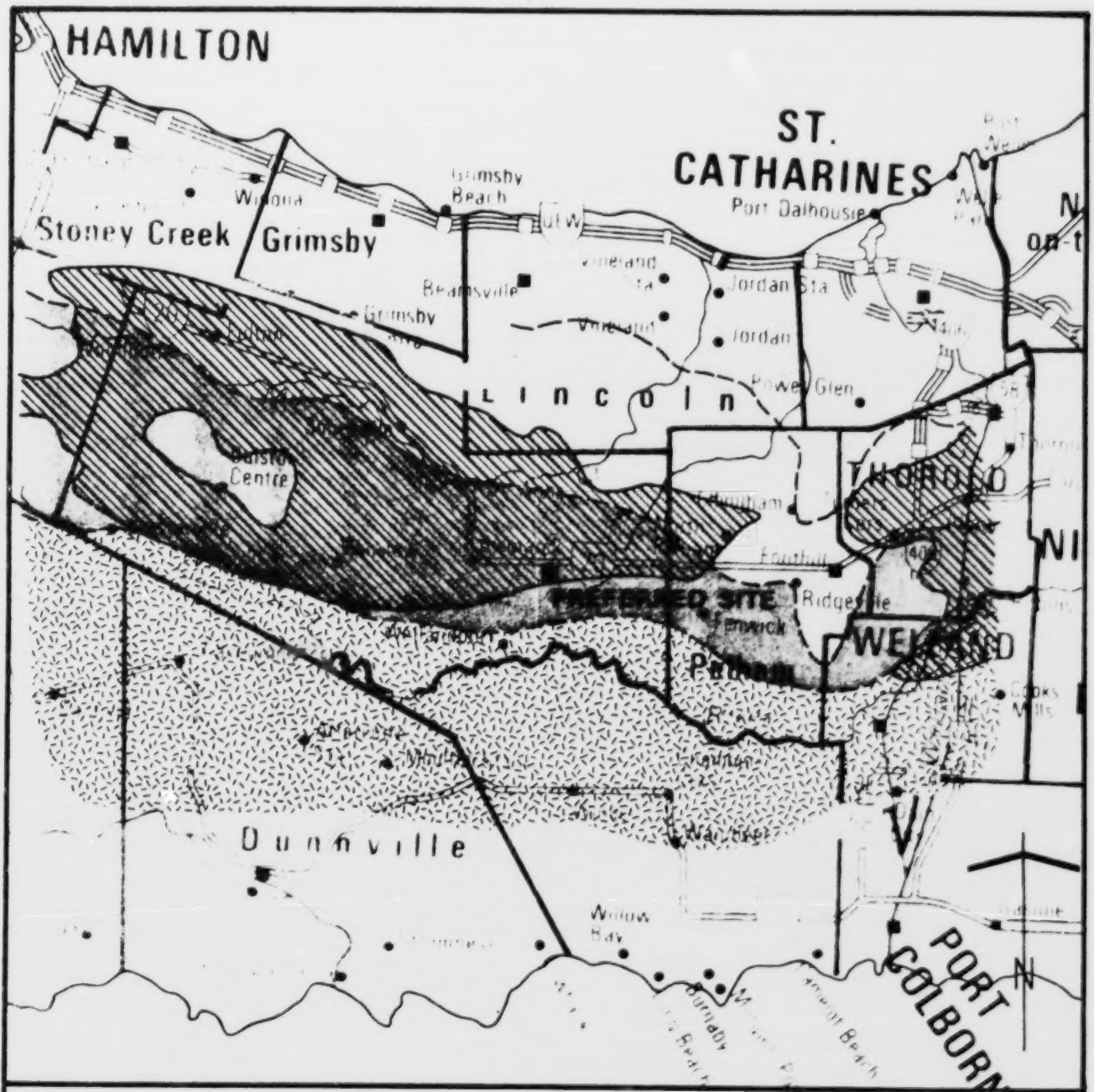


FIGURE 5-2
BEDROCK AQUIFER POTENTIAL

Legend

-  Salina formation
-  Guelph formation
-  Lockport-Amabel formation

 Highly productive zone (Turner, 1978)

Modified from GLAL 1984a

0 10
km

Municipal supplies for the Town of Smithville, about 10 km northwest of the Preferred Site, are developed in this aquifer. The Smithville Well No. 2, which is about 30 m deep, supplies about 500 to 800 m³/d of water from three waterbearing zones at 11 m, 20 m and 26 m. The hydraulic conductivity of the bedrock in the Town of Smithville based on pump testing in 1969 is 1E-4 m/s. A discussion of the hydrogeologic properties of the Guelph Formation at the Preferred Site is provided in Section 3.2.

According to Turner (1978) the "quality of water in the Guelph-Lockport Aquifer, although generally marginal, has not restricted its use for private domestic purposes". The water is generally hard and may locally contain elevated concentrations of iron, sulphate and chloride. "Sulphurous" water attributed to low concentrations of hydrogen sulphide is also reported in several well records available for the area. Water quality analysis results for samples collected from Smithville Well No. 2, during the pump test in 1969 are presented in Table 5-1. The analyses indicate the water exceeds Ontario Ministry of the Environment Water Quality Objectives (MOE, 1984) for sulphate and total dissolved solids.

The Salina Formation, which is present south of the Preferred Site consists of dolostones, shales and evaporite deposits. Locally, the Salina Formation is capable of yields in excess of normal domestic water requirements. Most wells obtain adequate supplies of water within 3 m of the bedrock surface.

Municipal supplies for the Town of Caledonia, about 35 km to the west of the Preferred Site, are provided by five wells completed in the Salina Formation (Sibul et al., 1980).

Water quality in the Salina Formation is generally poor due to the dissolution of evaporites. This results in locally high concentrations of calcium, sodium, potassium, sulphate and chlorides. Table 5-1 presents available information on water quality for select anions and total dissolved solids (TDS). The elevated concentrations for sulphate, chloride and TDS are indicative of poor water quality.

A more detailed discussion of ground water availability and quality in the immediate vicinity of the Preferred Site is provided in Section 5.3.

TABLE 5-1: GROUND WATER QUALITY, GUELPH AND SALINA FORMATIONS

LOCATION	CHEMICAL PARAMETERS*				SOURCE OF INFORMATION
	CHLORIDE Cl	SULPHATE SO	ALKALINITY (CaCo)	TDS	
Guelph Formation • Smithville Well No. 2 after 24 hr pump test after 48 hr pump test	27 32	884 708	288 284	- 1838	MOE Permit To Take Water File
Salina Formation • Wainfleet high low • Franconia sample #227	238 142 36 43	2805 2142 2079 2209	415 85 85 44	- - 3350 3600	O.W.R.C. Files Project WR2-68 MOE (Desaulniers, 1980) (Mellary and Aaltonen, 1973)
MOE WATER QUALITY OBJECTIVE Aesthetic Considerations	<250	<500	<500	<500	MOE (1983)

* all parameters expressed in mg/L

5.3 LOCAL GROUND WATER AVAILABILITY AND QUALITY

5.3.1 INTRODUCTION

The development of ground water as a source of supply is largely influenced by its availability, i.e., the presence of an aquifer(s) which can be developed to provide an adequate supply of water of suitable quality for its intended use.

Sources of ground water are developed using dug/bored and drilled wells. Dug/bored wells are generally completed in the shallow overburden while drilled wells may be completed in either the overburden or bedrock. Springs and ponds which may be sustained by ground water discharge are occasionally used as a source of supply.

Major identified water uses include:

(1) Domestic Use

- Potable - water used specifically for drinking
- Non-Potable - water used for domestic purposes other than drinking, includes cooking, washing, toilet use and other domestic uses.

(2) Livestock Use

- Livestock consumption rates are determined from published data or are estimated (Table H1-1, Appendix H1)

(3) Other Use

- includes specific uses such as spray water for agricultural chemicals, irrigation, commercial use, community use or other uses as specified.

Ground water supplies (availability and quality) in the vicinity of the Preferred Site are described in Sections 5.3.2 through 5.3.5. A summary of the field survey data is presented in Table H2-1, Appendix H2.

5.3.2 OVERBURDEN GROUND WATER SUPPLIES

Supplies are developed in the overburden using relatively shallow dug or bored wells. These wells are typically of large diameter (1.0 - 1.5 m) and generally are less than 20 metres in depth. Many older wells were dug by hand and are lined with stone. These wells are generally limited to depths of less than 10 metres. Well completion details are often not available for these older wells. More recently completed wells are usually bored and contain a concrete lined casing that is assembled in short segments. Gravel is generally used as backfill at the bottom of the hole and around the outside of the casing. Ground water is allowed to seep into the well through the joints between the casing segments and through the bottom of the well. These wells have reported depths of up to 17 m. Alternate methods of construction involve excavation with a backhoe as reported on parcel 10-163 (Figure 5-1).

There are 25 reported dug/bored wells within the study area (Figure 5-3). Most are quite old and are either not in use or have been abandoned and in some instances filled in. Only 11 (44%) of the reported wells are in use, (Table 5-2). For the most part these wells are reported as being used for domestic potable (7 wells) and non-potable (11 wells) purposes and are used to supplement other sources of water supply. Only one dug well, located on parcel 10-111, about 1 km west of the Preferred Site near Hwy 20 (Figure 5-3), is reported as the sole source of domestic water supply for a residence.

Consultant



Legend:

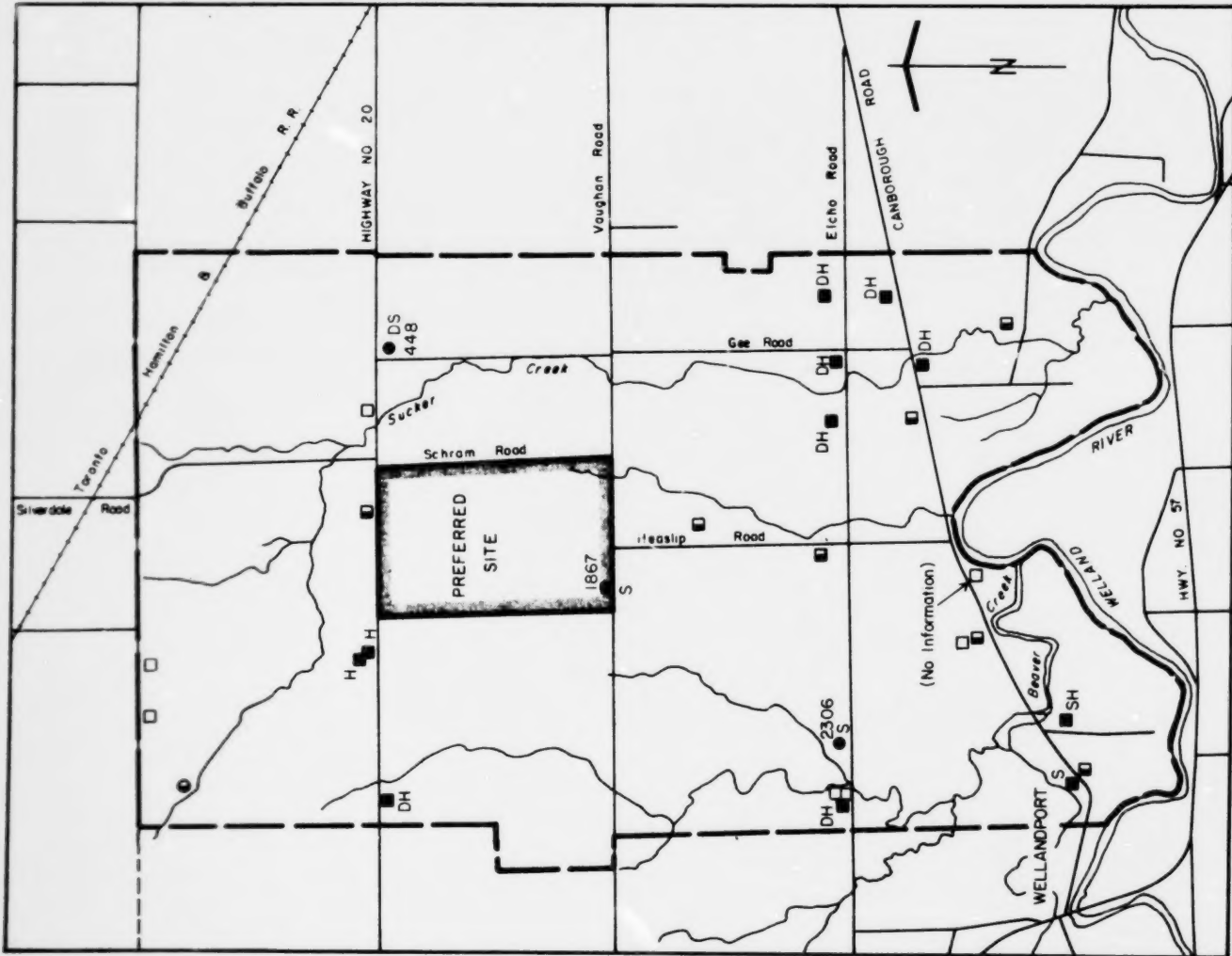
- , □ Dug/bored well; used, unused, abandoned
- , ○ Drilled well; used, unused
- ▬ Site boundary
- - - Study area boundary
- DSH Dug/bored well; used for drinking (D), stock (S) or non-drinking household (H) water supplies
- DSH Drilled well; used for drinking (D), stock (S) or non-drinking household (H) water supplies

448 Ontario Ministry of the Environment well reference number included where available (well details summarized in Table HI-1, Appendix HI)



**REPORTED WATER USE;
OVERBURDEN WELLS**

Figure 5-3



Four drilled wells are completed in overburden. Three of these wells have Ontario Ministry of the Environment well records (well reference no. 448, 1867 and 2306). These wells are located on parcels 6-302, 10-81 and 7-245, respectively (Figures 5-1 and 5-3). Well construction details are presented in Table H1-1, Appendix H-1. All three wells are in use.

Well no. 448 which is located about 1/2 km east of the Preferred Site is 33.8 m deep and is completed in gravel (depths of 32.9 to 33.8 m). The gravel is assumed to overlie the bedrock and may actually be weathered rock in that a neighbouring well (no. 2531) encountered bedrock at 32.9 m.

Well no. 1867 is located on the Preferred Site near the southeast corner and is 35.1 m deep. This well is also completed in gravel (depths of 34.8 to 35.1 m). Test drilling (borehole location 85-10) conducted about 150 m west of the well, encountered bedrock at 36.7 m. The gravel noted in the well record for well no. 1867 may correspond to the silt and sand till which overlie the bedrock in borehole 85-10-1 (location 85-10) or may be weathered bedrock. The till is described as a gravelly silt and sand with a trace of clay. Gravel content at this location increases to 40% with depth. The borehole log for 85-10-1 is presented in Appendix C1.

TABLE 5-2: OVERBURDEN WELLS - SUMMARY

Source	Total	In Use	Not In Use**	Not Known	WATER USE*		
					Domestic Use		Live-Stock
					Potable	Non-Potable	
Dug/Bored Wells	25	11	13	1	7	11	1
Drilled Wells	4	3	1	-	2	3	3
Total	29	14	15	1	9	14	4

* One or more water uses are assigned to a single source

** Not in use includes abandoned and unused wells

Well no. 2306 located about 1 km southwest of the Preferred Site is 34.8 m deep and is completed in shale and gravel (depths of 34.4 to 34.8 m). Bedrock was encountered at 36.0 m on an adjacent property (well no.2124, parcel 10-244).

The fourth drilled well, located on parcel 10-241 about 1.5 km northwest of the Preferred Site, was reported by the resident to be about 9.4 m deep. This well was drilled using a portable power auger. Thin gravel layers (0.1 m thick) were reported to have been encountered at depths of 6.7 m and 7.6 m. This well is silted in and is not in use.

Of the 29 overburden wells within the study area, 15 are either not in use or are abandoned (Table 5-2). The wells in use are most commonly reported as being used for domestic purposes; nonpotable (14 wells) and potable (i.e., drinking water) (9 wells) supplies followed by livestock watering (4 wells).

The quantity of water available from dug/bored wells is considered to be limited. Yields are considered to be relatively low and peak use is likely accommodated by water taken from storage within the well. Two recently completed bored wells were reported to be dry upon completion, but filled up slowly with water over a period of time (Parcels 10-163 located about 200 m northwest of the Preferred Site and 7-95-1 located on the eastern edge of Wellandport (Figure 5-1)).

5.3.3 BEDROCK GROUND WATER SUPPLIES

The majority of the water wells (65 of 94 wells representing 69% of the total wells) which have been constructed in the study area are completed in the bedrock. These wells were

constructed using cable tool or rotary drilling techniques. The wells generally contain 127 to 198 mm diameter casing and range in depth between 26.5 m and 49.7 m (Table H1-1, Appendix H1).

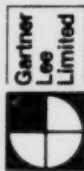
The bedrock wells are generally completed to depths of 30 m or greater within the study area and usually penetrate only the upper few metres of bedrock. Well records indicate that well yields of 0.6 to 0.9 L/s can be developed (Table H1-1, Appendix H1). One recently completed well, located about 0.7 km northwest of the Preferred Site was reported to have been pump tested at 7.6 L/s. Generally, supplies are reported to be adequate for household and livestock watering purposes.

Figure 5-4 shows the location of the water wells which are completed in the bedrock and Table 5-3 summarizes water use for these wells. These wells are completed either in the Guelph Formation or the Salina Formation (Figure 5-4). The contact between these two formations as shown in Figure 5-4, is located about 1 km south of the Preferred Site. It should be noted that the Guelph Formation underlies about two-thirds of the study area.

Only 42 wells of the 65 bedrock wells completed in the study area (about 65%), are currently being used. Of the wells which are not in use, 11 wells have been abandoned primarily because they are old wells in poor repair and the remainder, 12 wells are not in use for a number of cited reasons, including:

- replacement of the well by a new supply (well or cistern); and
- land use changes (discontinued farm operation or vacant residence).

Consultant



Legend:

●, ○, □ Drilled bedrock well; used,
unused, abandoned

— Study area boundary

▬ Site boundary

● DSH Drilled bedrock well used for drinking (D)
stock (S) and non-drinking household (H)
water supplies

2858 Ontario Ministry of the Environment well
reference number included where available
(well details summarized in Table HI-1,
Appendix HI)

1000 500 0 1000 metres

**REPORTED WATER USE;
BEDROCK WELLS**

Figure 5-4

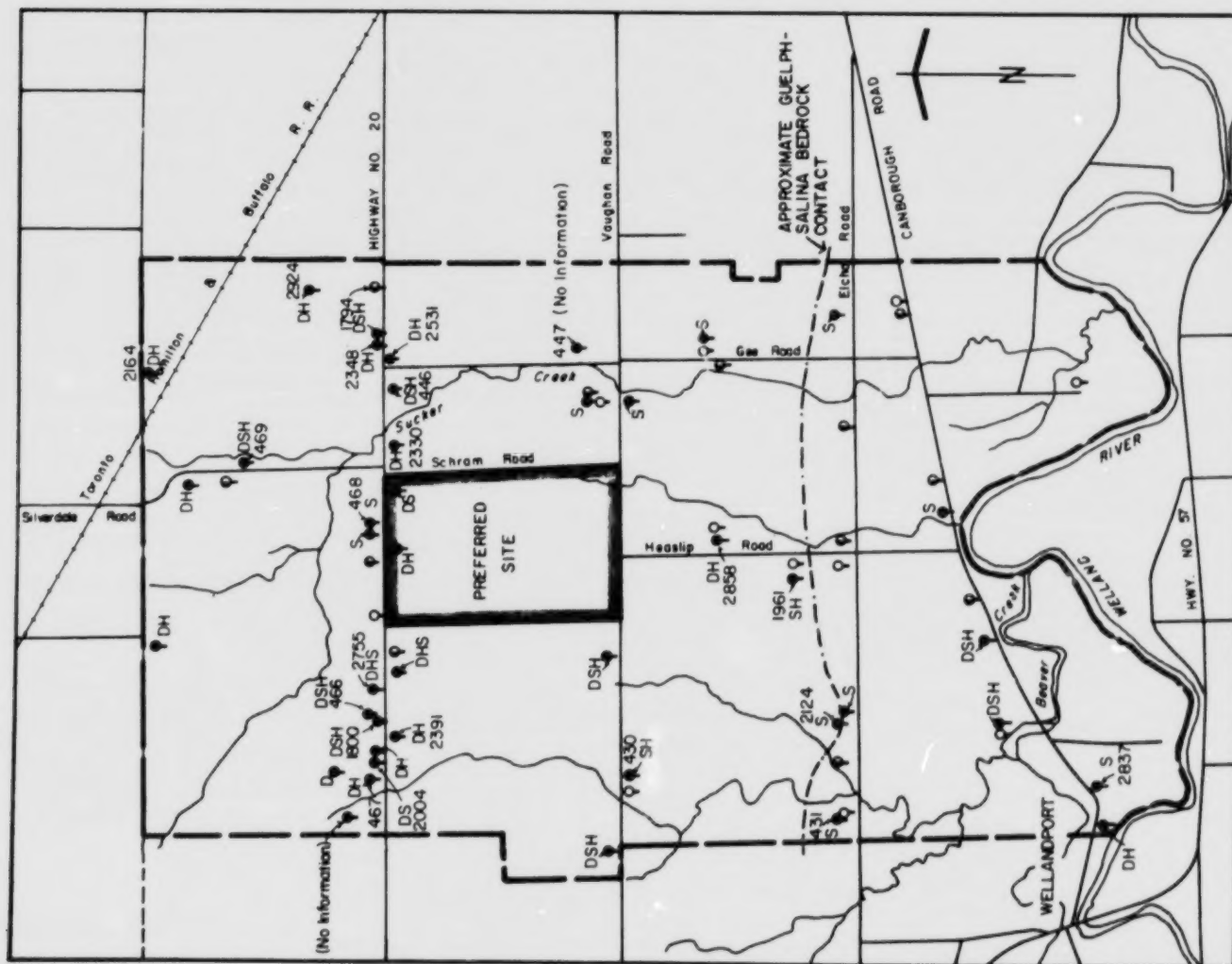


TABLE 5-3: BEDROCK WELLS - SUMMARY

Drilled Wells	Total	In Use	Not In Use**	No Information	Water Use*		
					Domestic Use Potable	Non-Potable	Livestock
Total	65	42	23	2	27	26	27
Guelph + Salina ++	46 19	34 8	12 11	2 -	24 3	23 3	19 8

+ Guelph - indicates area underlain by Guelph Formation

++ Salina - indicates area underlain by Salina Formation

* One or more water uses are assigned to a single source

** Not in use includes abandoned and unused wells

About 70% (46 of 65 wells) of the bedrock wells within the study area are located in the area underlain by the Guelph Formation. The remainder (19 wells) are in the area underlain by the Salina Formation.

About 74% (34 of 46 wells) of the wells located in the area underlain by the Guelph Formation are in use. Of these, 71% (24 of 34 wells) are used as a source of drinking water. Only 42% (8 of 19 wells) of the wells located in the area underlain by the Salina Formation are in use and only 38% (or 3 of 8 wells) of these wells are used as a source of drinking water supply.

The variation in reported water use may in part be attributed to differences in water quality between the two bedrock formations. As noted in Section 5.2, the water quality of the Salina Formation is generally poor, with locally high concentrations of calcium, sodium, potassium, sulphate and chloride. The water quality of the Guelph Formation is relatively good, although the water may locally be elevated in total dissolved solids, hardness and sulphates. A discussion of bedrock ground water quality in the vicinity of the Preferred Site is provided in Section 5.3.5.

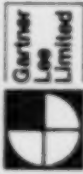
A number of the bedrock and gas exploration wells in the study area were reported to have been flowing at some time in the past. The location of these wells are shown in Figure 5-5. Three wells located immediately west of the study area, near Wellandport, are also included because of their proximity to the study area. Two of these wells are gas exploration wells which are currently capped. The third well is reported to be very old and its origin was not established.

Within the study area, wells which were reported to have flowed in the past are located on parcels 7-247, 7-240 and 7-2. Two of these wells are located on parcel 7-247, about 1.5 km southwest of the Preferred Site. One has been abandoned and was filled in about 30 years ago. The other well was constructed in 1958. Based on information on the Ontario Ministry of the Environment well records available for the well (reference number 431), the well is completed in shale at a depth of 36.6 m. The static level was reported to be 0.6 m below surface at the time it was constructed (Table H1-1, Appendix H1). This well was reported to have stopped flowing following the completion of a gas exploration well on an adjacent property, parcel 71-29. The gas well also flowed but has since been capped. The two wells on parcel 7-2; located about 2 km southeast of the Preferred Site, are very old and have been abandoned. One was reported to have been a gas well and the origin of the other is not known.

The well on 7-240, about 0.5 km southeast of the Preferred Site, was reported to be a source of water for livestock in the past but has since stopped flowing. This well is very old and its origin is not known.

OWMC Ontario
Waste Management
Corporation

Consultant



Legend:

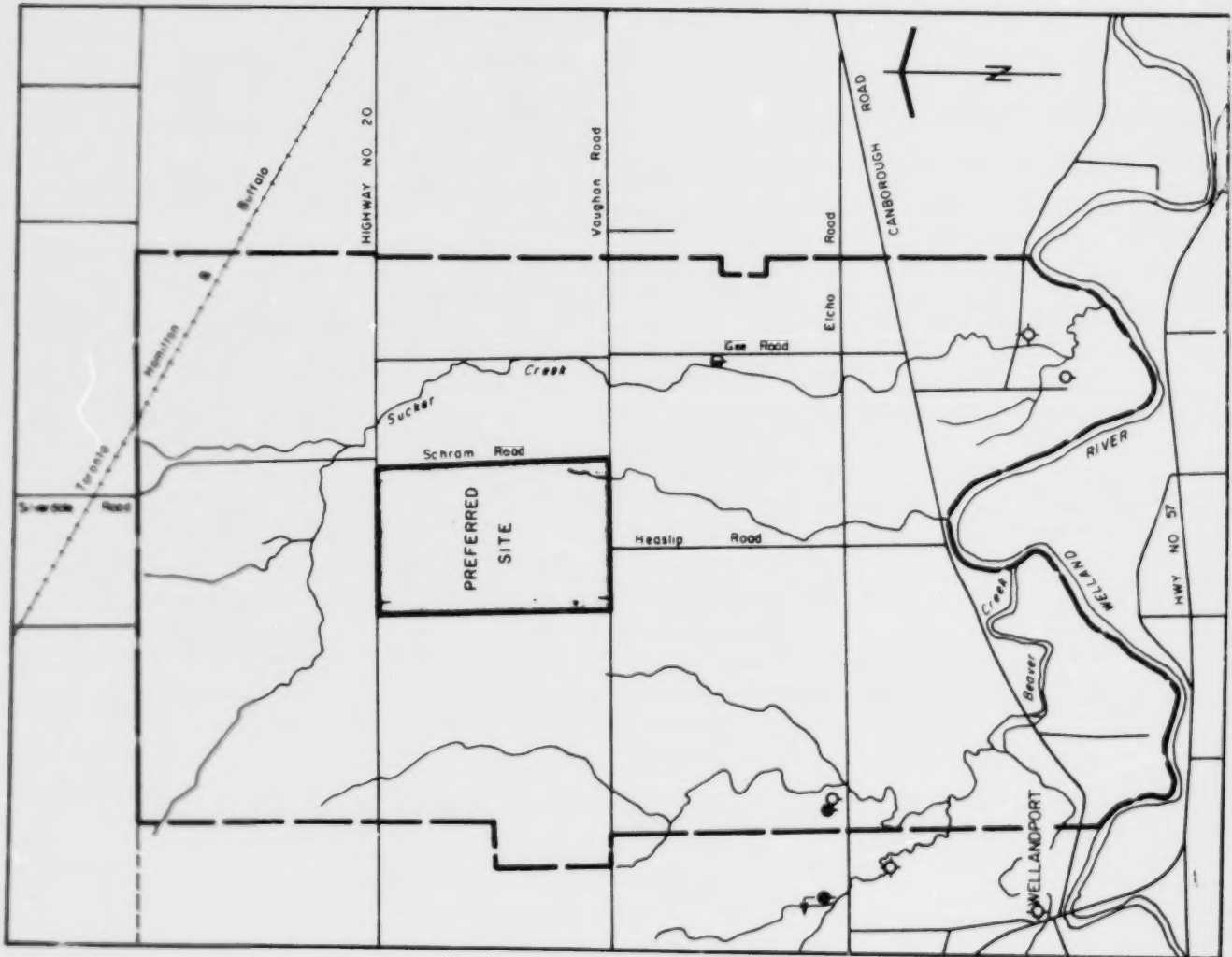
- , ○, ◐ Drilled bedrock well ; used ,
unused, abandoned
(reported to have been flowing in past)
- ◇ Abandoned or capped gas
exploration well
(reported to have been flowing in past)
- ↻ Flowing conditions
- - - Study area boundary
- Site Boundary

Note - None of the wells within the study area are
currently reported to be flowing

1000 500 0 1000 metres

REPORTED FLOWING WELLS

Figure 5-5



Flowing well conditions indicate that the static water level in the well is above the ground surface. This results in upward hydraulic gradients and correspondingly upward ground water flow. It is assumed that the majority of the "flowing" wells were initially drilled for gas exploration purposes and are generally completed deeper into the bedrock than local water wells. The static water levels for the shallower water wells are generally between 4 to 12 m below the ground surface (Table H1-1, Appendix H1).

Water levels were reported to have dropped for some drilled bedrock wells in the study area during construction of the Welland Canal realignments, about 25 km southeast of the Preferred Site. Some respondents have associated this with dewatering activities during the canal excavation.

5.3.4 OVERBURDEN WATER QUALITY

Very little information is available on the quality of water from the shallow dug/bored wells. Assuming that water collected from standpipes constructed at the Preferred Site as part of this program is representative of water from the dug/bored wells, the Ontario Drinking Water Objectives are significantly exceeded for total dissolved solids, hardness, sodium, sulphate and dissolved organic carbon and slightly exceeded for fluoride, iron, and manganese (Tables 4-2 and 4-4, Section 4.2).

Bacterial contamination was reported for one dug well located on parcel 10-111 located about 1/2 km west of the Preferred Site (Figure 5-1). This contamination was attributed to road construction activities in the vicinity of the well.

5.3.5 BEDROCK WATER QUALITY

Water quality was generally reported as "fresh" on the well

records for local bedrock wells (Table H1-1, Appendix H1). During the field survey, several bedrock wells were reported to have a noticeable "sulphur smell" and occasionally hard water quality and iron (Table H2-1, Appendix H2). The locations of these wells are shown in Figure 5-6.

Water quality deterioration was occasionally reported by local residents following the construction of wells on adjacent properties or as a result of seismic activity. For example, the water quality for a drilled well at parcel 10-101 (Figure 5-1) was reported as having deteriorated significantly following the completion of a gas well on an adjacent property (parcel 10-100). The water became discoloured (black) and a strong sulphur smell was noticed. The water quality in this well has since improved but the sulphur smell is reported to be still noticeable. Iron and the sulphur smell were reported to have increased in a drilled well at parcel 7-15 following an earthquake two to three years ago. The water in a few wells in the study area was reported to be "murky" at certain times of the year. In one case, on parcel 10-76 just east of the Preferred Site, murky water quality was attributed by the resident to test drilling undertaken during Phase 4A on parcel 10-105 in 1984.

Based on the analysis of water samples collected from monitors completed in the Guelph Formation at the Preferred Site, the water is of reasonably good quality. The Ontario Drinking Water Objectives are however, significantly exceeded for total dissolved solids, hardness, sulphate, dissolved organic carbon and slightly exceeded for fluoride and iron (Tables 4-2 and 4-4, Section 4.2). Low levels of hydrogen sulphide were also noted at some locations.

Consultant



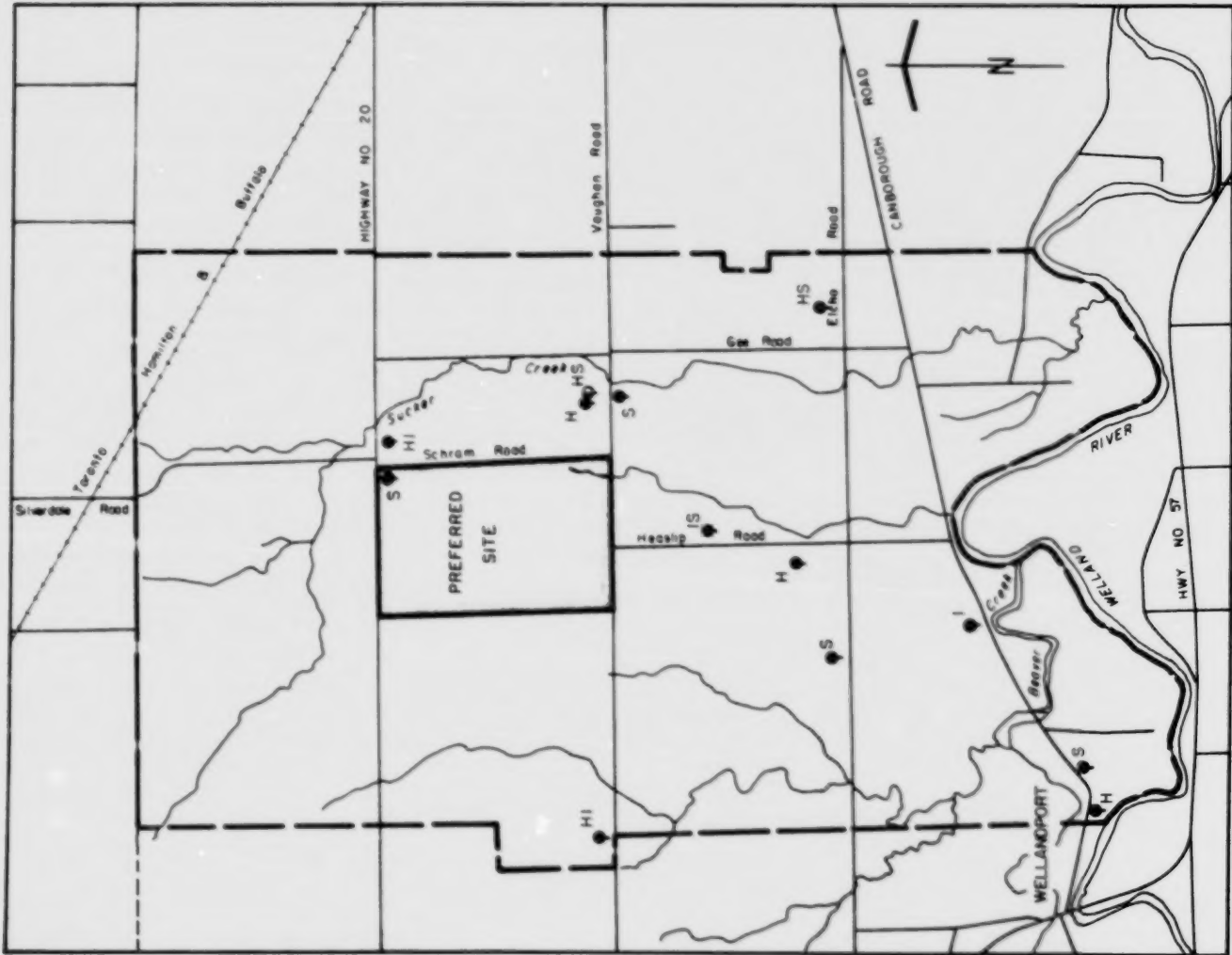
Legend:

- Drilled bedrock well ; used ,
○ unused , abandoned
- - - Study area boundary
- Site boundary
- H₂S Reported water quality problems,
hardness (H), iron (I) or 'sulphurous'
odour (S) H₂S

1000 500 0 1000 metres

REPORTED WATER QUALITY PROBLEMS

Figure 5-6



It was not possible to differentiate between the water quality of the Guelph and Salina Formations using reported water quality information collected during the water use survey. In addition, no water samples were collected from wells completed in the Salina Formation. Should it be necessary to collect information on the water quality of the Salina Formation in the future, preference should be given to water wells for which there are MOE well records.

5.4 ALTERNATIVE SOURCES OF WATER SUPPLY

5.4.1 INTRODUCTION

Alternative sources of water supply in the study area are rainwater, purchased water (trucked supplies), pond water and creek water. Many residents rely on more than one source of supply. A number of factors enter into the selection of a source of supply including its availability and reliability, the cost of development and potential water use demands (quantity and quality).

5.4.2 RAINWATER AND PURCHASED WATER

Rainwater collected from the roofs of buildings or water purchased from a commercial water supply contractor are major sources of water supply in the study area. This water is generally stored in cisterns. Cisterns are generally located below ground and are constructed of concrete or brick. Some of the older brick lined cisterns may function as shallow dug wells allowing ground water to seep into the cistern.

A total of 72 cisterns are reported in the study area (Table 5-4). The location of these cisterns is shown in Figure 5-7. Of these, 59 cisterns are in use. This includes two cisterns that are located east of the site but usage information was withheld during the interview, (two residences).

OWMCG Ontario Waste Management Corporation

Consultant



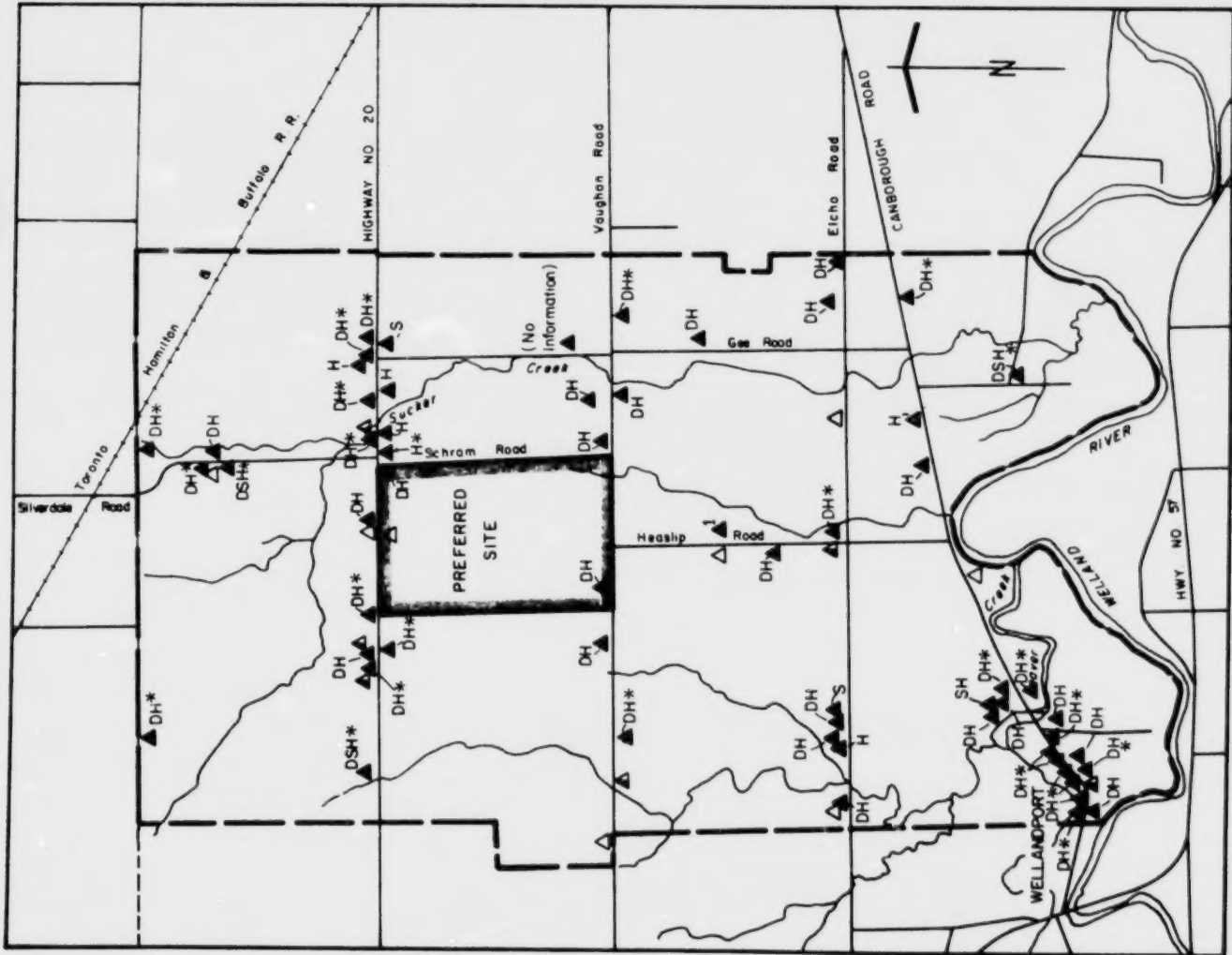
Legend:

- ▲,▲,△ Cistern; used, unused, abandoned
- Study area boundary
- Site boundary
- DSH Cistern used for drinking (D), stock (S) and non - drinking household (H) water supplies
- * Cistern used as sole source of water supply
- 1 Cistern used for vehicle washing only

1000 500 0 1000 metres

**REPORTED WATER USE;
CISTERNS**

Figure 5-7



Approximately 52 residences rely either partially or totally on cisterns as a source of supply (a few residences have more than one cistern). The majority of the cisterns are used for domestic purposes and only a few for livestock watering. One cistern is used for commercial purposes (auto repair), and another is located at the Wellandport Community Centre.

TABLE 5-4: CISTERNS - SUMMARY

No. of Sources	In Use	Not In Use**	Water Use*				Sole Source
			Domestic Use Potable	Domestic Use Non-Potable	Livestock	Other	
74	60	14	48	56	8	2	24

* one or more water uses are assigned to a single source

** not in use includes abandoned and unused wells.

A total of 38 (64%) of the actively used cisterns are replenished using both rainwater and purchased (trucked) water. Only 12 (20%) of the cisterns are replenished solely by rainwater and 7 (12%) solely by purchased water. The source of water for 2 cisterns, about 4% of the total, is unknown. Cisterns are reported as the sole source of water at 24 parcels of land which includes primarily domestic residences as well as the Wellandport Community Centre (Figure 5-7).

There is very little water quality information available for cisterns. A sulphur odour was reported from one old cistern at parcel 10-16, located about 1 km north of the Preferred Site. The majority of cisterns receive treated municipal water trucked in from outside the study area. Periodic chlorination is the most common form of water treatment reported for cisterns. In one instance, on parcel 7-153, at the eastern edge of Wellandport on Canborough Road, a layered filtering system using sand, gravel and charcoal, was used for treating cistern water.

A few individuals reported purchasing distilled water for drinking and in one instance, drinking water was obtained from a natural spring near St. David's, Ontario.

5.4.3 POND WATER AND SPRING WATER

Forty-five ponds were identified in the study area (Figure 5-8) including several ponds mapped from air photos. No water use information is available from those ponds mapped from air photos. Approximately one-half of the reported ponds are currently in use as a source of agricultural water, primarily for livestock watering and crop spraying. This is primarily a seasonal use which is discontinued during the winter months.

Domestic nonpotable water use is reported in a few cases. The use of ponds as a source of domestic drinking water is limited to two ponds located on parcel 7-143 about 2 km south of the Preferred Site. One of these ponds supplies four separate residences and the other pond supplies one residence and livestock. Another pond located on parcel 7-93-3 was reported to have been used for drinking water and non-potable water use by two residences, although use of the pond for drinking water was discontinued a few years ago due to poor water quality.

OWMCO Ontario Waste Management Corporation

Consultant



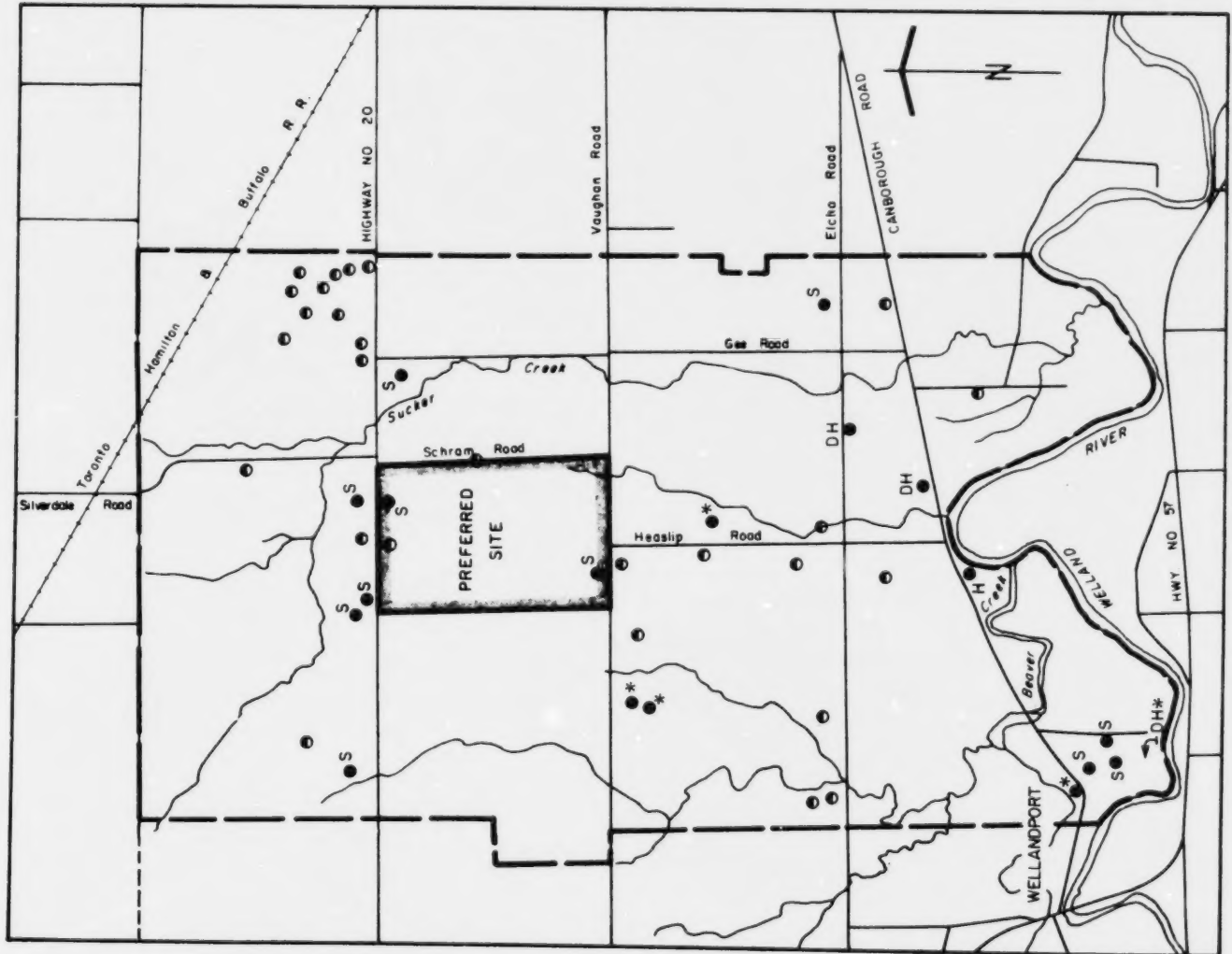
Legend:

- , ○ Pond ; used , unused
- ⌋ Spring location
- Study area boundary
- ▬ Site boundary
- DSH* Pond ; used for drinking (D), stock (S), non - drinking household (H) or other (*) use including agricultural spray water and garden irrigation.
- ⌋ DH Spring ; used for drinking (D) and non - drinking household use (H)

1000 500 0 1000 metres

REPORTED WATER USE ; PONDS & SPRINGS

Figure 5-8



The water quality from ponds used for drinking is reported to be good. Water from these ponds is filtered through a gravel bed into a wet well from which it is pumped to the residences. Periodic chlorination of the ponds is the only reported form of chemical treatment.

A number of springs are reported in the study area in the vicinity of the Welland River. A spring on parcel 7-96 supplies one residence with water that is used for drinking and non-potable purposes. The location of this spring is shown in Figure 5-8. Other springs or seepage areas are reported on parcels 7-2, 7-94-5, 7-149 and 7-149-5, although none of these are currently used as sources of water. The locations of these springs are shown in Figure 5-1 (in map pocket). The spring located on 7-149 was reported to have been used in the past as a source of water by local residents.

Water quality for the spring on parcel 7-96 is reported to be good, although it was reported that nitrate is present and the water quality deteriorates during periods of high water levels in the adjacent Welland River. Water treatment is limited to periodic chlorination.

5.4.4 CREEK AND STREAM WATER

Creeks and streams are occasionally used for livestock watering or garden watering. Most creeks and drainage ditches within the study area flow intermittently and are only infrequently available as a source of water. None of the creeks or streams were reported to be used as a source of domestic drinking water.

Some residents reported a gradual deterioration of water quality in the Welland River. Algal accumulations in the Welland River were reported to be particularly heavy in 1986.

5.5 ESTIMATE OF THE QUANTITY OF WATER USED FROM IDENTIFIED SOURCES

A summary of water use for the study area is provided in Table 5-5. Estimates of the quantities of water used within the study area are based primarily on water use (consumption) rates presented in published studies. In some instances, information on consumption rates is not available and it was necessary to assume that a certain rate was applicable to a particular use. The estimated water consumption rates for various uses are listed below along with the referenced information source.

$$\text{RESIDENTIAL WATER USE} = \frac{\text{water use per person}}{\text{per day (275 L/person/d*)}} \times \frac{\text{number of persons}}{\text{per household}}$$

+ lawn and garden watering
per household (1100 L/household/d**)

COMMERCIAL WATER USE

- | | |
|--------------------------------|---------------------|
| - Oxbow Restaurant | 5,000 L/d estimated |
| - Wellandport Community Centre | 857 L/d estimated |

AGRICULTURAL WATER USE***

- | | |
|--------------------------------|--------------|
| - milk cow (including washing) | 136 |
| - steer | 55 |
| - horse | 55 |
| - hog | 7 |
| - sheep | 7 |
| - chickens (100) | 23 |
| - turkeys (100) | 45 |
| - dog (kennel use per dog) | 10 estimated |
| - rabbit | 2 estimated |
| - ferret | 2 estimated |
| - goat | 7 estimated |
| - geese (100) | 45 estimated |

* from Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems (MOE, 1982)

** assumes lawn and garden area of 0.1 ha and 100 mm soil moisture deficit from June - August.

*** Farm water supply (OMAF, undated)

TABLE 5-5: ESTIMATED WATER USE IN STUDY AREA*

Water Use	Water Source				Total Water Use	Water Use Percentage
	Bedrock Wells	Overburden Wells	Cisterns	Surface Water		
Domestic	55.7	9.0	94.0	11.5	170.2	41.4%
Livestock	206.3	5.8	0.6	21.3	234.	57%
Spray Water				0.7	0.7	0.2%
Other**	5.0		0.9		5.9	1.4%
Total Water Use	267.0	14.8	95.5	33.5	410.8	100%
Total Water Use Percentage	65.0%	3.6%	23.2%	8.2%	100%	

* Water use in cubic metres per day (m /d based on consumption rates in published studies and reported usage, (Table H2-1, Appendix H2)

** Other uses include commercial and community use

Water use for individual parcels of land are documented in Table H2-1, Appendix H2. Where water is obtained from two sources of supply (e.g., well and cistern) it was assumed that each source provided 50% of the water used. It was not possible to quantify some water uses such as occasional or emergency use. In such cases, the quantity of water used was not estimated and has not been included in Table 5-5. In addition, no water use was estimated for those parcels where interviews were refused. Estimated water use, as shown on Table 5-5 is provided for major sources. These include:

- 1) Bedrock - provided from drilled wells
- 2) Overburden - provided primarily by dug, bored and drilled wells
- 3) Cisterns - water provided by rainwater, trucked-in or purchased water or a combination of these sources
- 4) Ponds and other - includes ponds, streams, creeks and springs.

The estimated use of water is also provided for specific uses including:

- 1) Domestic - includes drinking (potable use) and cooking, washing, etc. (non-potable use)
- 2) Livestock - includes livestock watering and associated use (i.e., cleaning of barns or pens and equipment)
- 3) Other - includes commercial use (i.e., restaurant, repair garage use) and community use (community centre use).

The total estimated water use for the study area is 411 cubic metres per day (m^3/d). Domestic use including drinking water and undifferentiated household water accounts for about $170 \text{ m}^3/\text{d}$ (41%), livestock watering about $234 \text{ m}^3/\text{d}$ (57%), agricultural spray water about $1 \text{ m}^3/\text{d}$ (<1%) and commercial and community use about $6 \text{ m}^3/\text{d}$ (1%). Bedrock wells supply about $268 \text{ m}^3/\text{d}$ or 65%, overburden wells $15 \text{ m}^3/\text{d}$ (4%), cisterns $94 \text{ m}^3/\text{d}$ (23%) and surface water $34 \text{ m}^3/\text{d}$ (8%).

Estimated water use for various sources of supply is not distributed uniformly across the study area. To demonstrate this, the study area was divided into two smaller areas, one represented by the area north of Vaughan Road and the other, the area south of Vaughan Road. The southern area includes all land parcels between the Preferred Site and the Welland River. The distribution of water use for these two smaller areas (north and south) is shown in Table 5-6.

Less water is used in the south in comparison to the northern portion of the study area. Domestic water use is fairly evenly distributed across the study area, while the majority of livestock water use occurs in the north (about 75% of total livestock use). All reported agricultural spray usage occurs in the south. The commercial and community water use includes the Oxbow Restaurant and the Wellandport Community Hall which are located in the south and north respectively.

Bedrock wells are the single most important source of water supply in the north, supplying an estimated $198 \text{ m}^3/\text{d}$ of water. Cisterns supply about $39 \text{ m}^3/\text{d}$, followed by surface water ($21 \text{ m}^3/\text{d}$) and overburden wells ($7 \text{ m}^3/\text{d}$). In the south, water use requirements are satisfied principally by

TABLE 5-6: DISTRIBUTION OF WATER USE IN STUDY AREA

WATER USE AND SOURCE OF SUPPLY	TOTAL WATER USE+			
	NORTH		SOUTH	
	m ³ /d	(% Total)	m ³ /d	(% Total)
DOMESTIC USE				
• bedrock wells	45	(27)	12	(7)
• overburden wells	2	(1)	7	(4)
• cisterns	39	(23)	54	(32)
• surface water	-	-	12	(7)
Sub-Total	86	(51)	84	(50)
LIVESTOCK USE				
• bedrock wells	148	(63)	58	(25)
• overburden wells	5	(2)	1	-
• cisterns	-	-	-	-
• surface water	21	(9)	-	-
Sub-Total	175	(75)	59	(25)
AGRICULTURAL USE*				
• surface water	-	-	1	(100)
Sub-Total			1	(100)
COMMERCIAL AND COMMUNITY USE*				
• bedrock wells	5.0	(85)	1	-
• cisterns	-	-	-	(15)
Sub-Total	5.0	(85)	1	(15)
TOTAL WATER USE				
• bedrock wells	199	(48)	70	(17)
• overburden wells	7	(2)	8	(2)
• cisterns	39	(10)	55	(13)
• surface water	21	(5)	12	(3)
TOTAL	266	(65)	145	(35)

* agricultural use is for crop spraying and is based on total reported use of 108,600 litres over the period May to September.

+ figures rounded to nearest %.

bedrock wells ($70 \text{ m}^3/\text{d}$) and cisterns ($55 \text{ m}^3/\text{d}$) followed by surface water ($12 \text{ m}^3/\text{d}$) and overburden wells ($8 \text{ m}^3/\text{d}$).

It is also evident from Table 5-6 that greater usage is made of bedrock wells as a source of supply for both domestic and livestock watering purposes in the north ($194 \text{ m}^3/\text{d}$) versus the south ($70 \text{ m}^3/\text{d}$). In addition, greater usage is made of cisterns in the south ($55 \text{ m}^3/\text{d}$) than in the north ($39 \text{ m}^3/\text{d}$). This is likely attributed to water quality differences in the underlying bedrock as noted in Section 5.2.2.

5.6 POTENTIAL (FUTURE) WATER USE

Water use in the study area reflects the existing residential and agricultural land use pattern. In predicting future water use, it is necessary to develop an appreciation of anticipated future land use patterns. QWMC's land use consultant concluded in their Phase 4A report that "no urban residential or industrial development is anticipated within 5 km of either candidate sites (the Preferred Site and LF-3C) by the year 2001. The rate of population growth in the hamlet and rural areas is expected to continue at historical levels, in the 1.0% to 1.6% per annum range" (Leon Kentridge Associates Ltd., 1985).

Assuming that land use in the study area will continue to be a mixture of rural residential and agricultural use, water supplies are likely to continue to be provided by individual supply systems.

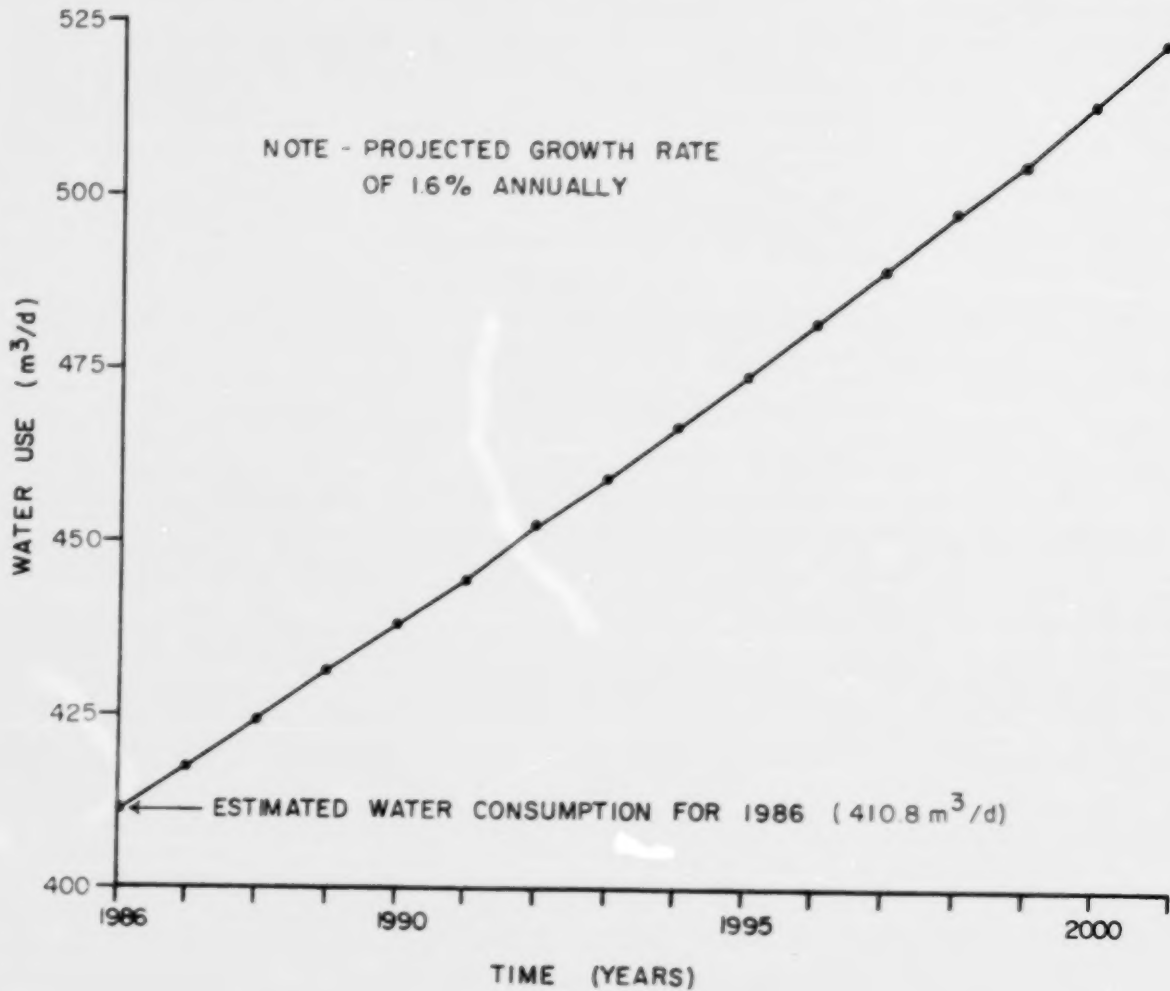
The sources of supply are likely to remain diverse (i.e., ground water, rain water etc.), and the demand is anticipated to reflect the anticipated population growth rate of 1.0 to

1.6% per annum. Assuming an annual increase in water demand of 1.6%, water use within the study area will increase from the estimated total use of 411 m³/d for 1986 to about 521 m³/d by the year 2001. The increase in water consumption is shown graphically in Figure 5-9.

Future changes in land use and water use resulting from the construction of the proposed OWMC facilities have not been considered in this assessment.

FIGURE 5-9

Projected Water Use For The Vicinity Of Preferred Site



6-1

6.0 GEOTECHNICS

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6.0 GEOTECHNICS

6.1 INTRODUCTION

6.1.1 PURPOSE AND SCOPE

Results of the Phase 4B preliminary geotechnical program undertaken at OWMC's Preferred Site, are discussed in this section.

The principal objectives of the geotechnical portion of the study were to provide:

- a geotechnical classification of the subsoils and a preliminary assessment of the engineering properties;
- an adequate data base for the conceptual design of landfill excavation slopes, foundations and construction considerations (input to engineering consultants); and
- a preliminary indication of soil handling characteristics (input to engineering consultants).

The geotechnical studies were closely coordinated with the other elements of the Phase 4B geoscience program, particularly the geologic and physical hydrogeologic components. The major tasks of the geotechnical component included:

- review of existing data;
- field investigations;
- laboratory analyses;
- preliminary assessment; and
- reporting.

Within this section of the report, only the factual aspects of the geotechnical subsurface conditions are presented. The engineering interpretation and implication of these results, as they might affect the design of the landfill excavation, foundations and general construction aspects are discussed in Site Assessment - Phase 4B: Geotechnical Input to Facilities Design (GLL, 1987a). Technical terms used within this section are defined in Section 8.0 of this report.

This section of the report should be read in conjunction with the remainder of the Site Assessment - Phase 4B: Geology, Hydrogeology and Geotechnics, Baseline Conditions report.

6.1.2 BACKGROUND

This study builds on the geotechnical interpretation developed during the Phase 4A studies. The Phase 4A interpretation was based mainly on a review of published geotechnical studies undertaken in the general geographic area. One important study, the Welland Canal realignment, provided insight into the anticipated engineering properties of the soils in the area. Both the Welland Canal and the Preferred Site are situated on the Haldimand Clay Plain. The same soil units appear to be present in both areas. However, the units are thicker and seem to demonstrate less stratigraphic complexity in the vicinity of the Preferred Site.

In the investigation of a site situated on clayey soils, there are several soil characteristics that are of significance from a geotechnical standpoint. These are:

- shear strengths for both drained and undrained field conditions to assess long and short term stabilities;

- the variation of shear strength relative to the orientation of the angle of load application and slope geometry (strength anisotropy effects);
- consolidation and preconsolidation characteristics relative to the design of foundations;
- soil mineralogy, chemistry, fabric and structure. The presence of active swelling clay minerals, parallel clay platelet fabric and soil stratification and fractures can affect shear strengths and failure plane geometries; and
- stratigraphic sequence relative to excavation geometry.

In reviewing the available Welland Canal data, the following characteristics of the soils emerge as being especially pertinent and consequently warrant consideration during: (1) this phase; (2) later detailed geotechnical investigations; and (3) subsequent construction activities at the Preferred Site:

- (1) A considerable undrained shear strength anisotropy was observed in the lower stratified clay identified as the Lower Glaciolacustrine Unit in Section 2.0 of this report. For example, up to 30% reductions in undrained strength were obtained on samples tested at angles of 45 to 60 degrees to the vertical. (Lo and Milligan, 1967; Conlon et al., 1971; DeLory and Lai, 1971; Conlon and Isaacs, 1971). The upper homogeneous clay (Halton Unit) was found to be only slightly anisotropic, the soil yielding up to 25% reductions in strength on "horizontal" samples. (Lo and Milligan, 1967).

- (2) Significant anisotropy of the effective stress strength parameters was also observed especially for the stratified units (Conlon et al., 1971; Lane, 1968).
- (3) The lower stratified clay exhibited a very pronounced clay platelet parallelism which brought peak and residual strength parameters close in value. (Quigley, 1971; Quigley and Ogunbadejo, 1972). In addition, an estimated 6 to 7% vermiculite was identified in some of the clayey layers (Quigley, 1969).
- (4) Due to low strengths and strength anisotropy in the lower units, very flat slope angles were required for the portal entry slopes to obtain an adequate reserve 'Factor of Safety' against failure (Conlon et al., 1971).

The Phase 4A work recognized the properties of the glacio-lacustrine units as being of prime importance for design of stable slopes, excavations and foundations for the Welland Canal construction. The Phase 4B geotechnical study program was designed to investigate in a preliminary way, the significance of these factors as they relate to the Preferred Site.

6.1.3 METHODOLOGY

The geotechnical program consisted of the following five major tasks:

- review of existing data (Background Section);
- field investigations;
- laboratory analyses;
- preliminary assessment; and
- reporting.

The published information from the Welland Canal reports, the Phase 4A report, as well as other published data in the general geographic area were compiled and reviewed. These data provided insight into the general subsurface conditions, as well as an indication of the soils' physical properties. Pertinent references are listed in Section 7.0.

The field investigations consisted of two main components:

- (1) subsurface drilling, soil and rock sampling and monitoring of ground water installations; and
- (2) a review of natural slopes along the Welland River.

Information from the Phase 4A and Phase 4B boreholes formed the basis for the evaluation of geotechnical conditions at the Preferred Site. The locations of these boreholes are shown in Figure 2-1. Borehole logs for both the 4A and 4B drilling programs are in Appendix C1.

During Phase 4B, a continuous cored borehole, terminated in bedrock, was drilled at each of twelve on-site locations. Approximately 5 m away from this first drilling location, a second borehole was advanced into the Lower Till unit. Standard sampling with both split-spoon samplers and Shelby tubes was carried out in the second borehole. In most instances the sampling intervals of the Shelby tubes were determined based on the preliminary results from the first borehole. A detailed description of the drilling and sampling protocols is presented within Appendix A1.

Split-spoon samples from the boreholes were sealed in plastic bags and were placed in core boxes for subsequent

description and classification. Shelby tube samples were transferred directly from the site to Golder Associates (Eastern Canada) Ltd. soil mechanics laboratory in Mississauga for storage and testing.

In addition to the subsurface drilling program, a brief site reconnaissance of the natural slopes along portions of the Welland River, directly south of the site, was conducted. The objective of this work was to observe the long term behaviour of natural slopes composed of similar clayey soils. The results of this review are discussed in GLL, 1987a.

Laboratory testing was carried out on a wide selection of samples to determine the index properties, shear strengths and consolidation characteristics of the various soil units. All laboratory testing was carried out by Golder Associates (Eastern Canada) Ltd. who made the actual selection of the test specimen from each specified tube or split spoon sample. Results of the Golder testing are presented in full in Appendix E1. The undrained strength anisotropy of the stratified lacustrine clays was studied by cutting a series of samples at angles to the axis of the extruded shelly tube samples. This meant that each test was run on a different sequence of laminae. A certain amount of variability resulted that would not have occurred had block samples been obtained. This problem requires further attention in subsequent geotechnical investigations. Many of the laboratory test results and the soil stratigraphy are also presented on the borehole logs in Appendix C1 of this report.

On completion of the laboratory program, these data together with the results of the drilling program were

compiled. These data formed the basis of the geotechnical assessment of the Preferred Site. Generalized soil properties and classifications were based on visual and tactile examination of the soil samples and laboratory test results. Due to the apparent sensitivity of the soil subunits, Standard Penetration Test results ("N" values) were used only to provide a relative guide to in-situ conditions.

Throughout the course of the geotechnical program, a close liaison was maintained with GLL's geotechnical conceptual advisor Dr. R. M. Quigley, P.Eng.

6.2 SOIL ENGINEERING PROPERTIES

In Section 2.0 of this report, a detailed discussion is presented describing the stratigraphic units on the basis of geologic interpretation. In this section of the report the units are described in terms of their soil engineering properties.

For convenience, the geologic names of the four main stratigraphic units, described in Section 2.0, have been retained for use in this section of the report. These units proceeding vertically from ground surface to depth, that is youngest to oldest, are:

- (1) Upper Glaciolacustrine Unit;
- (2) Halton Unit;
- (3) Lower Glaciolacustrine Unit; and
- (4) Lower Till.

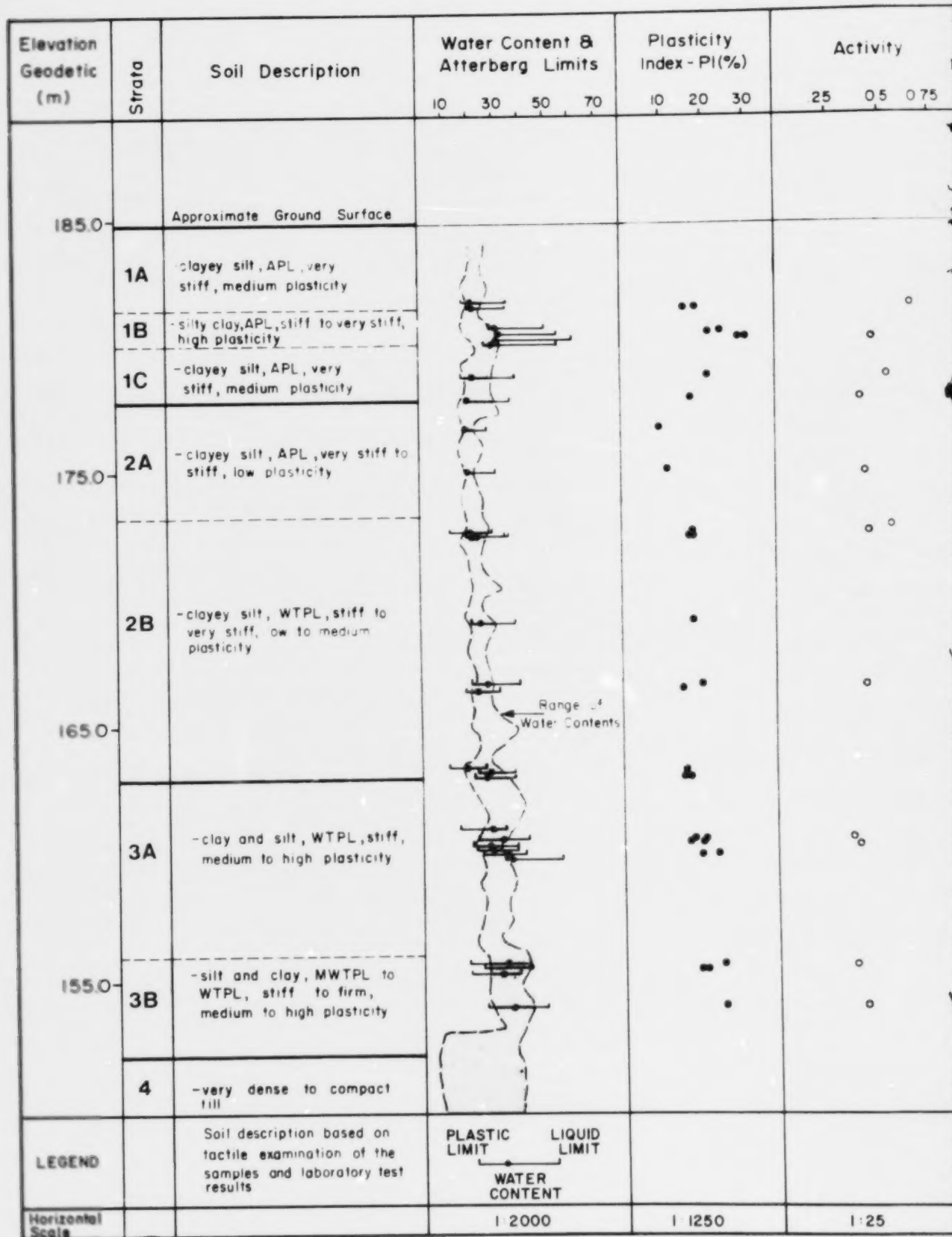
In order to present a visual overview of the site (geotechnically) and to determine the variability of the soil

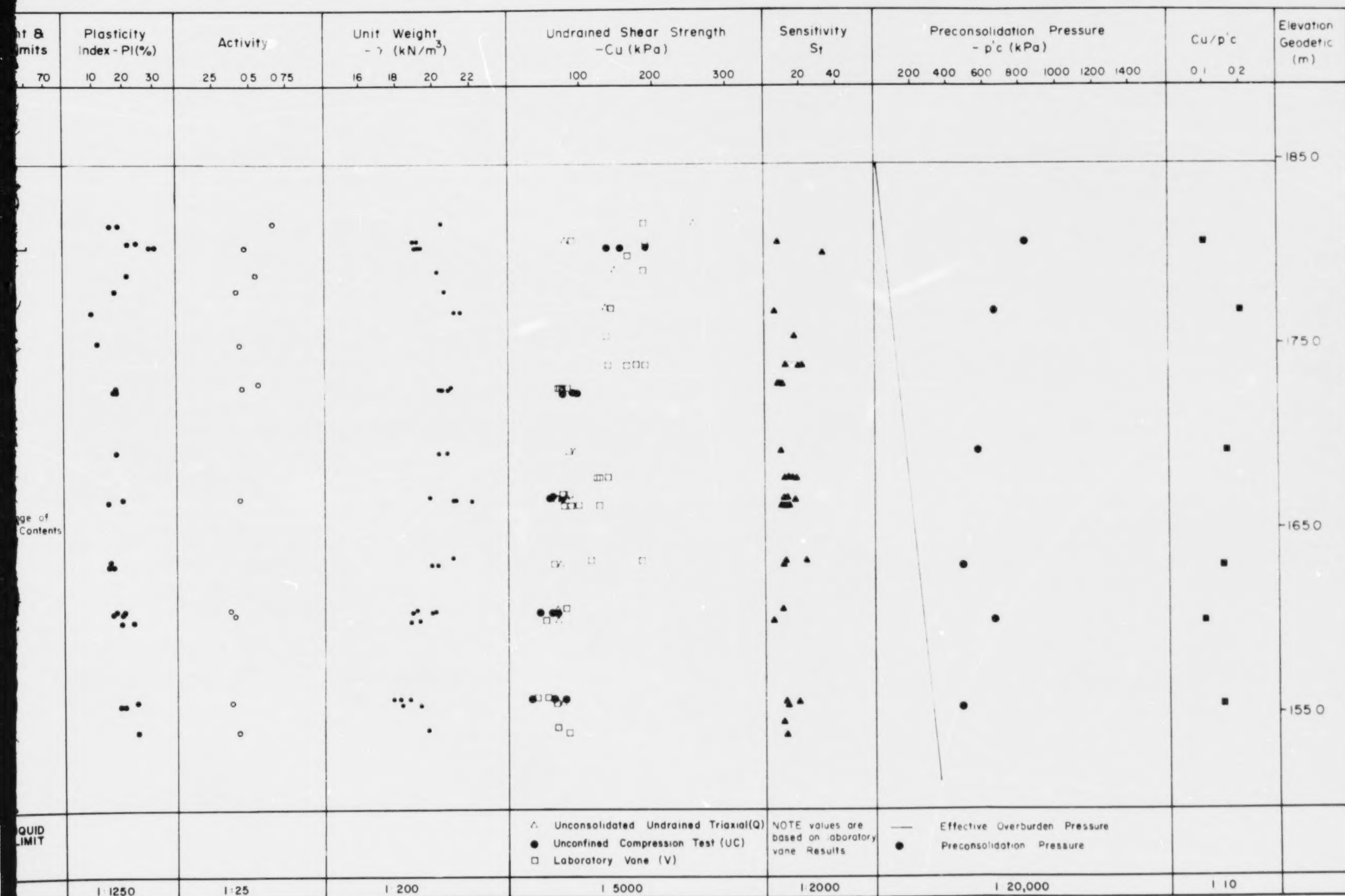
properties within the above units and subunits across the site, the results of some of the laboratory testing program are summarized graphically in Figure 6-1. The variation in plasticity of the units is also shown in Figure 6-2.

As would be expected, there is some scatter in the laboratory results. However, the preliminary data collected to date indicate that the soils' properties within each stratum, laterally across the site, are fairly similar. However, it is apparent in Figure 6-1 that there are variations in physical properties vertically between the various units and subunits. In some instances these variations are only slight. A brief summary of the changes in the index properties between the units and subunits are presented in Table 6-1. More detailed discussions of the soil engineering properties of the four main stratigraphic units are presented in Sections 6.2.1, 6.2.2, 6.2.3 and 6.2.4.

In general terms, the stratigraphy shown in Figure 6-1 displays the following trends:

- Six consolidation test data points suggest a marked increase in the preconsolidation pressure towards surface. This corresponds with the general increase in shear strength towards surface and corresponding water contents that are near the plastic limit near surface.
- The activity is relatively constant at 0.5 to 0.4 with depth, indicating generally inactive clayey soils.
- There is a general decrease of undrained strength with depth to an approximate elevation of 165 m.a.s.l. which corresponds with a decrease in preconsolidation pressure





OWMC Ontario Waste Management Corporation

Consultant



Legend

- 1 Upper Glaciolacustrine Unit
- 2 Halton Unit
- 3 Lower Glaciolacustrine Unit
- 4 Lower Till Unit
- A-C Indicates Subunits

OTPL Drier than plastic limit

APL About the plastic limit

ATPL Wetter than plastic limit

WATPL Much wetter than plastic limit

Vertical scale to 200
Horizontal as shown at the base of each column

SITE ASSESSMENT PHASE 4B

Geology, Hydrogeology
And
Geotechnics, Baseline
Conditions

FIGURE 6-1

Variation of Physical Soil
Properties with Elevation
(summary plot)

Figure 6-2: PLASTICITY CHART

SITE ASSESSMENT, PHASE 4B

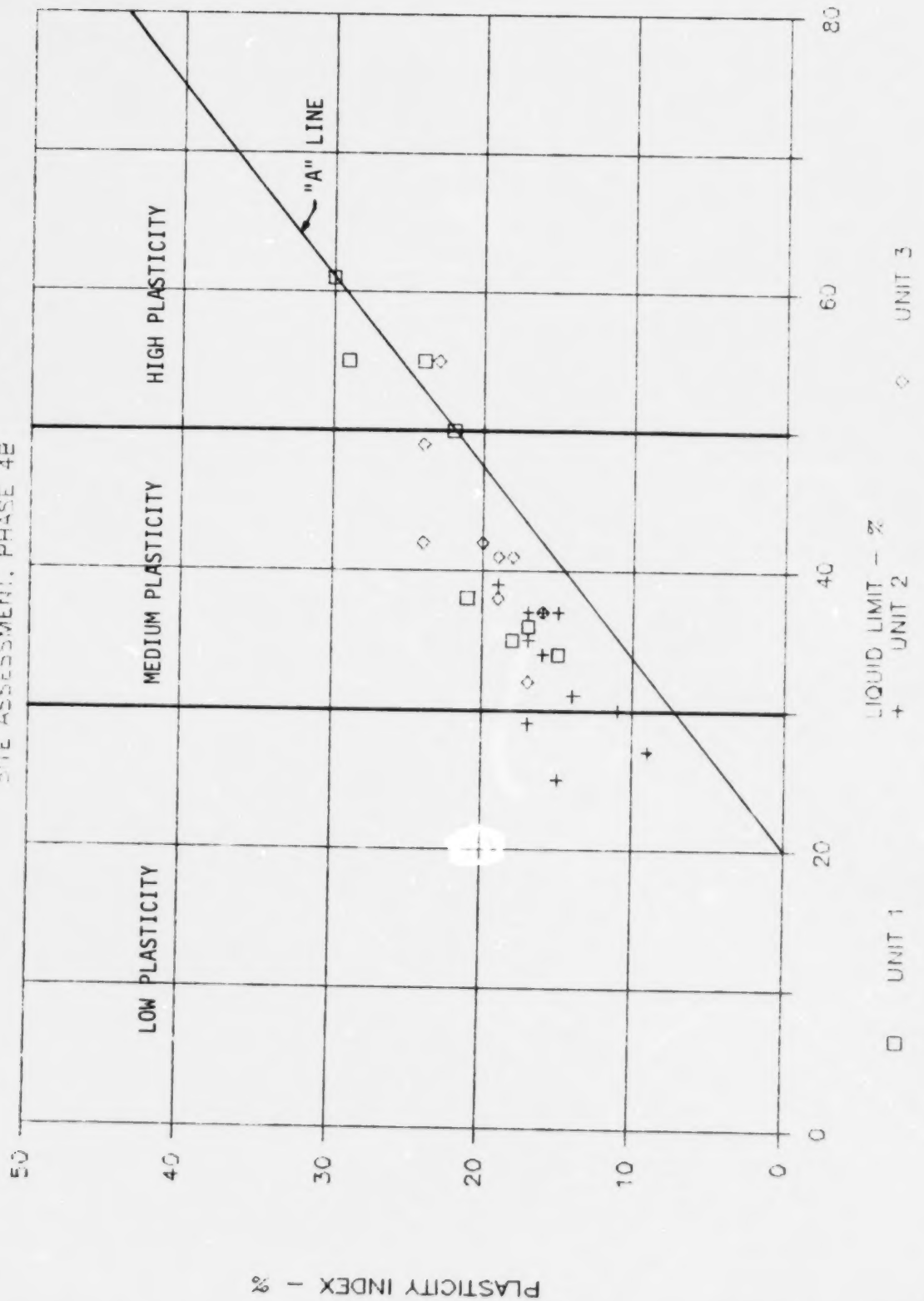


TABLE 6-1. VARIATION OF INDEX PROPERTIES BETWEEN SUBUNITS

UNIT	SUBUNIT	SOIL CHARACTERISTIC PROPERTIES	BASIS FOR DIVISION
1 - Upper Glacio-lacustrine Unit	1A	clayey silt, very stiff, medium plasticity	- increased plasticity and water content within 1B. - lower unit weight and shear strength within 1B.
	1B	silty clay, stiff to very stiff, high plasticity	- within 1C the plasticity decreases and the strength and unit weight increases.
	1C	clayey silt, very stiff, medium plasticity	- the plasticity of subunit 2A is lower than 1C and the unit weight is higher. However, the undrained shear strength of the two units (2A and 1C) is similar.
2 - Halton Unit	2A	clayey silt, very stiff to stiff, low plasticity	- the main difference between subunits 2A & 2B is the increased moisture content and slight decreased strength in 2B.
	2B	clayey silt, very stiff to stiff, low to medium plasticity	- the contact between 2B & 3A is highlighted by an increase in water content and decrease in unit weight. This is a reflection of the increased clay content within the Lower GlacioLacustrine.

TABLE 6-1. VARIATION OF INDEX PROPERTIES BETWEEN SUBUNITS (cont'd.)

UNIT	SUBUNIT	SOIL CHARACTERISTIC PROPERTIES	BASIS FOR DIVISION
3 - Lower Glacio-lacustrine Unit	3A	clay and silt, stiff, medium to high plasticity	- the contact within Unit 3 has been identified based on the increased moisture content and decrease in strength.
	3B	silt and clay, stiff to firm, medium to high plasticity	- the contact between the Lower Glaciolacustrine and Lower Till was very evident based on visual and tactile examination of the samples.
4 - Lower Till	4	very dense to compact till	

with depth. Below this elevation strengths appear relatively constant.

- Zones of higher water content typically correlate with lower unit weights.

The elevation of the contacts between the four main stratigraphic units, suggested by slight changes in the physical properties, seemed close to the average contact elevation determined during the geologic logging of boreholes.

6.2.1 UPPER GLACIOLACUSTRINE UNIT

In general, the Upper Glaciolacustrine Unit can be described as an overconsolidated, clayey silt of medium to high plasticity. As previously discussed, the Upper Glaciolacustrine Unit has been subdivided into three subunits based on observed differences in physical properties. The following section provides a more detailed description of each of the three subunits. The laboratory test results for samples from the entire unit are tabulated in Table 6-2. Grain size analyses carried out on samples of the three subunits are presented in Figures E2-1 and E2-2, in Appendix E2, respectively.

6.2.1.1 Subunit 1A

The uppermost subunit of the Upper Glaciolacustrine Unit is approximately 3.3 m thick and can be described as a faintly laminated clayey silt (Figure E2-1, Appendix E2). Based on visual and tactile examination of the samples, the material is brown, weathered, mottled, fissured, with a water content approximately at its plastic limit. With two liquid limits on one sample, in the order of 35%, subunit 1A is considered to be of medium plasticity.

TABLE 6-2: SUMMARY OF LABORATORY RESULTS, UPPER GLACIOLACUSTRINE UNIT

PAGE 1 of 1

SUBMIT: B.H. No.	SAMPLE No.	DEPTH (m)		WATER CONTENT: (%)	LIMITS		PI (%)	PI (%)	TOTAL UNIT WEIGHT: (kN/m ³)	DRY UNIT WEIGHT: (kN/m ³)	Gs	n (%)	e	SP (%)	CONSOLIDATION DATA			UNDRAINED SHEAR STRENGTH			EFFECTIVE SHEAR STRENGTH			Test Type
		FROM	TO		w _p (%)	w _L (%)	CLAY (%)	PI (%)							eo	p ^c (kPa)	K (m/s)	Cu (kPa) (peak / residual)	Strain: (%)	Test Type: (0 or UC) -Vane(V)	St	phi' (Degrees) (p-peak r-residual)	c' (kPa)	Test Type: -Triaxial -Direct Shear
85-																								
1B	12-2	4	2.7	3.4	20.8	29.8												186.4 <	V	0 deg				
1A	8-2	4	2.74	3.35	20.6													251.9	3.5	0 deg				
1A	8-2	4	2.74	3.35	20.8													186.4 <	V	0 deg				
1A	8-2	4	2.74	3.35	20.8													186.4 <	V	0 deg				
1B	5-2	6	4.28	4.89	31.8	27.5		18	0.55	17.25								79.5	2	0 deg			p 20	T
1B	5-2	6	4.28	4.89	31.8													86.9 / 12.6	2	0 deg			p 32	
1B	5-2	6	4.28	4.89	31.8													86.9 / 12.6	2	0 deg			p 32	
1B	3-2	6	4.28	4.89	31.8	66.6		22	0.45	19.05								189	1.5	UC 0 deg			p 19	DS
1B	3-2	6	4.28	4.89	31.8													151.8	6	UC 45 deg			p 0	
1B	3-2	6	4.28	4.89	31.8													134.5	4.5	UC 90 deg			p 0	
1B	1-2	7	5.03	5.64	28.5	22.1												23.9	20	UC 0 deg			p 0	
1B	1-2	7	5.03	5.64	28.5													9.9	20	UC 0 deg			p 0	
1C	8-2	7	5.5	6.11	29.5	56.4												166.5 / 5.2	V	0 deg			p 21	DS
1C	8-2	7	5.5	6.11	29.5	38.8		21	0.54	20.14								145.6	4.5	0 deg			p 20	
1C	8-2	7	5.5	6.11	29.5													186.4 <	V	0 deg			p 0	
1C	8-2	7	5.5	6.11	29.5													186.4 <	V	90 deg			p 0	
1C	8-2	7	5.5	6.11	20.7													186.4 <	V	236 deg			p 0	
1C	10-2	7	5.5	6.11	19	42.8		17	0.4	20.53								186.4 <	V	58 deg			p 21	DS

θ Angle of Test From Vertical

* Average of Three Results; ** Optimum Water Content; *** Maximum Dry Unit Weight;

LEGEND

w _L	Liquid Limit	n	Porosity
w _p	Plastic Limit	e	Void Ratio
PI	Plasticity Index	Sr	Degree of Saturation
A	Activity	Q	Quick Undrained Triaxial Test
Gs	Specific Gravity	UC	Unconfined Compression Test
		p ^c	Preconsolidation Pressure
		St	Sensitivity

phi' Effective Angle of Internal Friction
c' Effective Cohesion

Based on vertically oriented laboratory undrained shear strength values in excess of 186 kPa and tactile examination, it is inferred that subunit 1A is very stiff in consistency throughout its thickness. It is apparent from the preconsolidation pressure profile in Figure 6-1 that the material is heavily overconsolidated (i.e. the preconsolidation pressure is much greater than the present effective overburden pressure).

One set of consolidated undrained triaxial tests with pore pressure measurements was performed on one tube sample from this subunit. As shown in Table 6-2, the results yielded a peak effective angle of internal friction (ϕ'_{peak}) of 32 degrees with a corresponding effective cohesion (c'_{peak}) of 20 kPa.

6.2.1.2 Subunit 1B

Underlying subunit 1A was a relatively thin (approximately 1.5 m thick) stratum of a laminated silty clay of high plasticity. Field examination and water contents indicated that soil was generally at or near its plastic limit. (See water content and plastic limit data in Table 6-2 and in Figure 6-1).

The most obvious difference between subunits 1A and 1B is the increased plasticity of subunit 1B which yielded liquid limit values as high as 61%. This may be due to an increased clay size of the soil particles rather than a difference in mineralogy since similar values of activity were obtained on both subunits. This subunit forms an important part of the upper slopes of the proposed excavations at the site, hence the soil mineralogy may require special attention in subsequent studies.

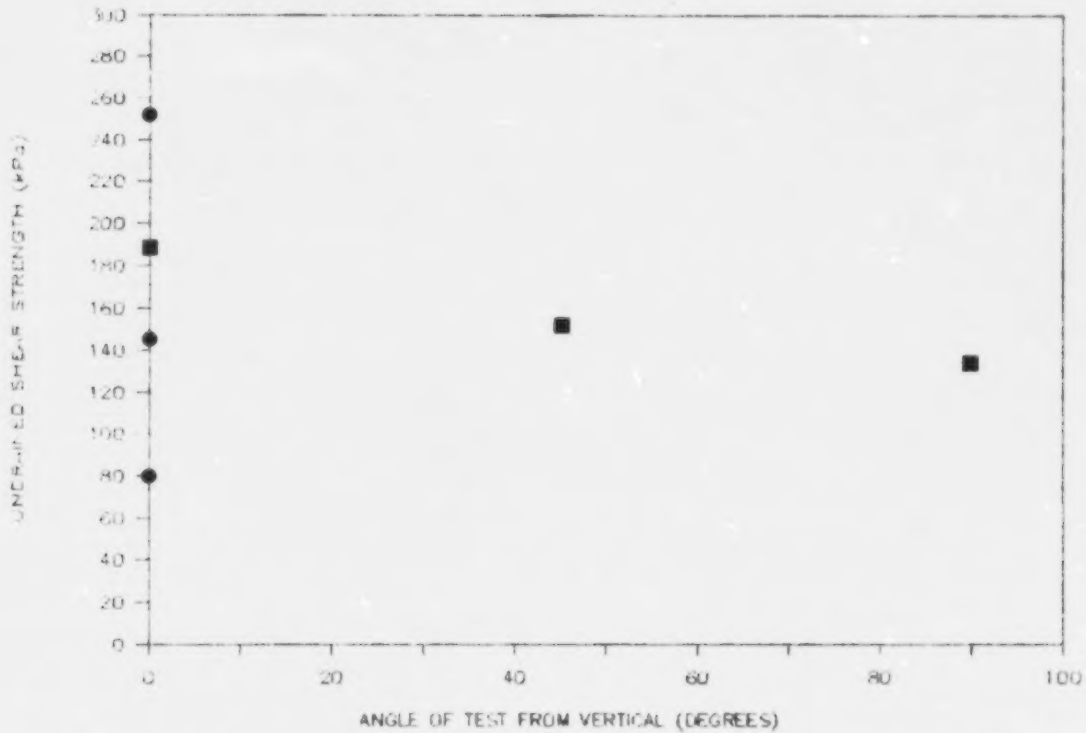
As presented in Table 6-2 and Figure 6-1, the undrained shear strength obtained on one sample was only 80 kPa suggesting a stiff consistency. Other factors (water content, preconsolidation profile) suggest further testing would indicate a stronger soil and a very stiff consistency throughout.

Direct shear testing on one tube sample from this subunit yielded lower effective shear strength parameters of ϕ' peak equal to 19 degrees and c' equal to 0 kPa.

As discussed in Section 6.1.2, a marked strength anisotropy has been previously measured by others within the soil units of the Haldimand Clay Plain. To address whether this situation existed within subunit 1B, three undrained shear strength tests were carried out at various orientations to the sample's vertical axis. Preliminary test results for samples from subunit 1B are presented in Figure 6-3. Three unconfined tests suggest a 30% decrease in undrained shear strength between the vertical ($i = 0$ degrees) and horizontal ($i = 90$ degrees) orientation. This implies that the available shear strength in a horizontal direction may be 30% less than in the vertical direction. In view of the importance of strength anisotropy to the behaviour of the upper slopes at the site, careful attention should be paid to this problem in future work.

A single compaction test was carried out on a sample of this subunit (Figure 46 in Appendix E1 - Golder report). This particular sample yielded an optimum moisture content of 16% and a maximum dry weight of approximately 17.1 kN/m^3 . The approximate average in situ moisture content of the subunit is 24%. The results of two unconfined compression tests that were

FIGURE 6-3: VARIATION OF SHEAR STRENGTH WITH THE ANGLE OF TESTING, UNIT 1



LEGEND

- Unconfined Compression Test
- Quick Triaxial Test

carried out on recompacted samples, at two moisture contents above optimum, are also plotted in Figure 46, Appendix E1. The two strengths of 10 and 24 kPa at water contents of 25% and 22%, respectively suggest that these soils may be quite sensitive to post excavation wetting.

6.2.1.3 Subunit 1C

The lower portion of the Upper Glaciolacustrine Unit is similar in texture to subunit 1A. Subunit 1C, however, does not appear to have undergone any weathering in recent geologic years as indicated by the closed and infilled fractures present and uniform grey-brown colour of the soil. The vertically oriented laboratory strength testing and tactile examination indicates the soil to be of a very stiff consistency.

The peak effective shear strength parameters, as determined by one test, (ϕ' of 21 degrees, c' of 8 kPa) were obtained from one set of direct shear tests. Corresponding residual values of 20 degrees and 0 kPa were also obtained on the same specimens.

6.2.2 HALTON UNIT

The Halton Unit has a somewhat complex geologic history, consisting as it does of up to five water-lain till sheets separated by lacustrine clays. In general, however, the physical properties of the Halton Unit do not appear to vary to a large extent, probably because all layers are very clayey.

For purposes of this section, the Halton Unit has been tentatively divided into two subunits 2A and 2B. As noted in

Table 6-1, this division has been based primarily on a slight increase in moisture content and liquid limit and a slight decrease in strength with depth. Those properties common to both subunits are described next. The observed variations in the physical properties within each subunit are then discussed under their respective headings. The laboratory test results for the Halton Unit are summarized in Table 6-3.

Texturally, the Halton Unit can be described as a clayey silt with trace to some amounts of sand and gravel size particles. The textural distribution of the till portions of the Halton are shown in Figure E2-3, Appendix E2. Grain size distributions for the lacustrine sediments within the Halton Unit are shown in Figures E2-4 and E2-5.

A single compaction test was also carried out on a composite sample of subunits 2A and 2B taken from 10.7 to 12.8 m depth. The results of this test are shown in Figure 47 of Appendix E1 and indicate an optimum moisture content of 15.6% and the maximum dry unit weight is 17.9 kN/m^3 . Since the average in situ moisture content of the Halton Unit is approximately 23%, it is possible that at least the lower half of this Unit is significantly wetter than optimum. Undrained shear strength tests carried out on recompacted samples wet of optimum are also shown in Figure 47. As in the case of the subunit 1B, remoulded samples wet of optimum yield very low strengths.

6.2.2.1 Subunit 2A

Moisture content determinations within subunit 2A indicate values close to two plastic limit values of 18 and 19%. Vertically oriented undrained shear strength tests were

TABLE B-3: SUMMARY OF LABORATORY RESULTS, WALTON UNIT

SUBUNIT	B.H. No.	SAMPLE No.	DEPTH (m)		WATER CONTENT (%)	CLAY (%)	LIMITS		A	TOTAL UNIT WEIGHT (kN/m3)	Gs	n (%)	e	Sr (%)	CONSOLIDATION DATA		UNDRAINED SHEAR STRENGTH		EFFECTIVE SHEAR STRENGTH		Test Type				
			FROM	TO			wp (%)	pl (%)							eo (kPa)	K (m/s)	Cu (kPa) (peak / residue)	Strain: Test Type (%)	St	phi' (Degrees)		c' (kPa)	Test Type		
85-	2A	5-2	10	8.08	8.69	17.8			21.38	18.14		33.4	0.5	99			133.4	7	0	0 deg					
	2A	5-2	10	8.08	8.69	17.8					2.78				0.54	556	4.8E-10	140.3	28.3	5	0.2				
	2A	5-2	11	9.6	10.21	21.1	30.4	9	27	18								135.1	8.4	16					
	2A	12-2	10	9.6	10.2	17.6	26.6												186.4	0	0 deg				
	2A	12-2	10	9.6	10.2	19.5													173.9	8.4	19				
	2A	12-2	10	9.6	10.2	16.8													163.4	8.4	20				
	2A	12-2	10	9.6	10.2	18.1													137.2	12.6	11				
	2A	5-2	13	9.76	10.37	19.3	28.5												38.9	20	0C	0 deg			
	2A & 2B	3-2	10 & 11	10.7	12.8	18.7		0.42	30	19		17.73							16.7	20	0C	0 deg			
	2A & 2B	3-2	10 & 11	10.7	12.8	20.8				20.71	17.45									20	0C	0 deg			T
	2A & 2B	3-2	10 & 11	10.7	12.8	15.6				21.15	17.51														
	2B	8-2	12	11.58	12.19	20.5					17.85									77.5	10.5	7			
	2B	8-2	12	11.58	12.19	20.1														66	7.3	9			
	2B	8-2	12	11.58	12.19	19.4														70.2	9.4	8			
	2B	8-2	12	11.58	12.19	20														71.2	9.4	8			
	2B	3-2	11	12.2	12.8	20.5	30.8		29	12	17	0.55	20.91	30.3	0.57	100				73.7	15	0	0 deg		
2B	3-2	11	12.2	12.8	22.3	38.5		35	16	17	0.44	20.92								8	0 deg				
2B	3-2	11	12.2	12.8	21.8			34	18			16.94								15	0 deg				
2B	3-2	11	12.2	12.8	22.3				20.23			16.61								20	0C	45 deg			
2B	5-2	18	15.7	16.31	22.5				20.36			16.65								15	0C	90 deg			
2B	5-2	18	15.7	16.31	22.5				20.69			16.89								13	0	0 deg			
2B	5-2	18	15.7	16.31	24															9	0 deg				
2B	10-2	16	15.7	16.3	18.5	11.6			20.19		2.78				0.68	560	3.2E-10								
2B	12-2	15	15.7	16.3	22	18.8															0 deg				
2B	12-2	15	15.7	16.3	21																90 deg				
2B	12-2	15	15.7	16.3	22																232 deg				
2B	12-2	15	15.7	16.3	22																53 deg				

Angle of Test From Vertical

* Average of Three Results; ** Optimum Water Content; *** Maximum Dry Unit Weight;

LEGEND

wl Liquid Limit
wp Plastic Limit
PI Plasticity Index
A Activity

n Porosity
e Void Ratio
Sr Degree of Saturation
eo Initial Void Ratio
p'c Preconsolidation Pressure

K Hydraulic Conductivity
Cu Undrained Shear Strength
Q Quick Undrained Triaxial Test
UC Unconfined Compression Test
St Sensitivity

phi' Effective Angle of Internal Friction
c' Effective Cohesion

TABLE 6-3. SUMMARY OF LABORATORY RESULTS, HALTON UNIT

SUBMIT	B.H. No.	SAMPLE No.	DEPTH (m)	FROM	TO	WATER CONTENT (%)	CLAY (%)	LIMITS			A	TOTAL UNIT WEIGHT (kN/m ³)	DRY UNIT WEIGHT (kN/m ³)	Gs	n (%)	e	Sr (%)	CONSOLIDATION DATA			UNDRAINED SHEAR STRENGTH			EFFECTIVE SHEAR STRENGTH		
								w _L (%)	w _P (%)	PI (%)								mo	p ^c (kPa)	K (m/s)	Cu (kPa) (peak residual)	Strain (%)	Test Type	phi' (Degrees)	c' (kPa)	Test Type
											% CLAY															
85-																										
28	6-2	17	17.68	18.29	26.6	44.2		39	20	19	0.43	19.79	15.63													
28	6-2	17	17.68	18.29	26.6																					
28	6-2	17	17.68	18.29	26.6																					
28	3-2	15	18.3	18.9	22.2			31	17	14		22.04	18.03													
28	3-2	15	18.3	18.9	22.2																					
28	3-2	15	18.3	18.9	21.7							21.02	17.22													
28	3-2	15	18.3	18.9	22.3							21.15	17.3													
28	1-2	21	18.74	19.35	22.6	38.6																				
28	1-2	21	18.74	19.35	23.5																					
28	1-2	21	18.74	19.35	20.7																					
28	1-2	21	18.74	19.35	22.2																					
28	10-2	20	20.3	20.9	17.7	25.9		25	10	15		21.08														
28	10-2	19	20.3	20.9	22.6	26.9																				
28	10-2	19	20.3	20.9	17.3																					
28	5-2	23	21.78	22.4	26.4			37	22	15		19.8	15.67													
28	5-2	23	21.78	22.4	26.4																					
28	5-2	23	21.78	22.4	25			37	21	16		20.17														

θ Angle of Test From Vertical

* Average of Three Results; ** Optimum Water Content; *** Maximum Dry Unit Weight;

LEGEND

w_L Liquid Limit
w_P Plastic Limit
PI Plasticity Index
A Activity
Gs Specific Gravity

n Porosity
e Void Ratio
Sr Degree of Saturation
mo Initial Void Ratio
p^c Preconsolidation Pressure

K Cu
Q Quick Undrained Triaxial Test
UC Unconfined Compression Test
St Sensitivity

phi' Effective Angle of Internal Friction
c' Effective Cohesion

carried out on samples within subunit 2A (Figure 6-1 and Table 6-3). Based on these strengths which range from 186 kPa to 133 kPa and tactile examination of the soil, the consistency of the subunit is inferred to be very stiff to stiff.

Results of a single set of triaxial tests yielded a peak ϕ' value of 28 degrees and a peak c' value of 20 kPa.

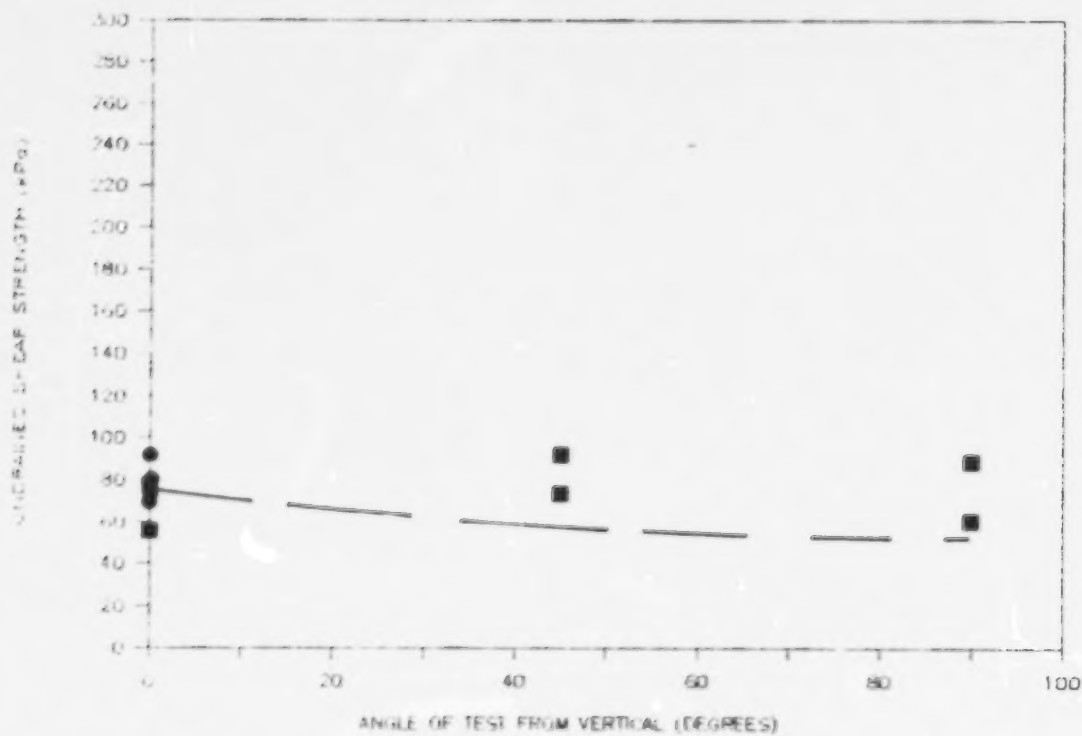
6.2.2.2 Subunit 2B

Approximately 11.8 m below existing ground surface, the Halton Unit seems to be generally wetter than its plastic limit. Vertically oriented undrained shear strength within subunit 2B ranged from in excess of 122 kPa to 56 kPa, suggesting a very stiff to stiff consistency. In general, the soil is believed to be of a stiff consistency with a slight decrease with depth, in spite of the scatter shown in Figure 6-1.

Figure 6-4 shows the variation of shear strength testing with various angles of orientation to the vertical axis and the Shelby tube samples. Based on these test results, the subunit 2B appears to exhibit very little strength anisotropy. Insufficient testing was done to confirm or disprove the results presented by Lo and Milligan, 1967, (Figure 6-4), which did suggest some anisotropy for some portions of the Halton Unit.

Two sets of direct shear tests carried out on two tube samples from subunit 2B yielded peak ϕ' values of 22 and 29 degrees and corresponding peak c' values of 20 and 7 kPa. The lower friction angle was likely obtained on a lacustrine portion of the Halton Unit while the higher friction angle probably reflects the granular portions of the till. The low

FIGURE 6-4: VARIATION OF SHEAR STRENGTH WITH THE ANGLE OF TESTING, UNIT 2B



LEGEND

- Unconfined Compression Test
- Quick Triaxial Test
- After Lo and Milligan, 1967

effective cohesion intercept of 7 kPa for the sample collected at a depth of 21 m may be a reflection of the decreasing overconsolidation of the Halton Unit with depth. The same tests yielded residual ϕ values of 21 and 28 degrees and residual c values of 0 kPa.

6.2.3 LOWER GLACIOLACUSTRINE UNIT

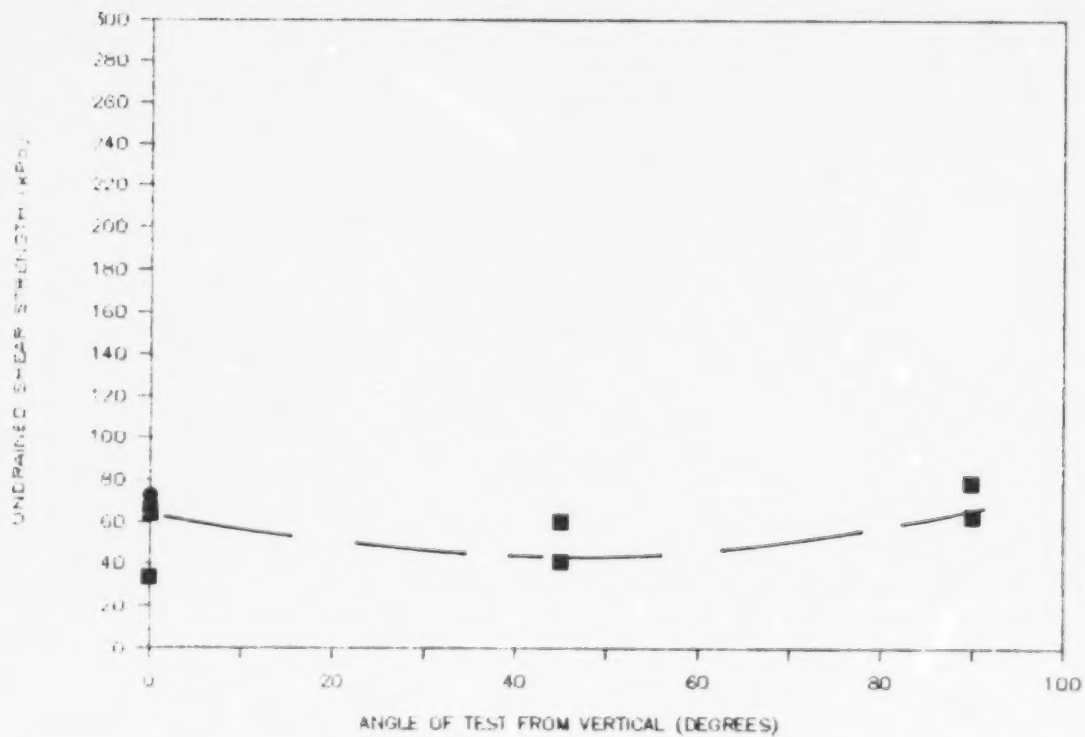
In general, the Lower Glaciolacustrine Unit which underlies the Halton Unit can be described as a silt and clay to a clay and silt of medium to high plasticity.

The strength anisotropy within the Lower Glaciolacustrine Unit was the factor that governed the design of the Townline Road - rail tunnel, near Welland. For this reason a number of special strength tests were performed on samples from this Unit.

Figure 6-5 presents the results of undrained unconfined shear strength testing carried out at various angles of orientation to the vertical axis of the Shelby tube samples. For comparison purposes, the trend obtained by Lo and Milligan (1967) for the soils from the Townline Road - rail tunnel are also presented in Figure 6-5. Insufficient testing was done to confirm or disprove the results presented by Lo and Milligan, 1967, which did suggest some anisotropy for portions of the Lower Glaciolacustrine Unit. As pointed out in the Methodology Section, resolution of this problem at the Preferred Site will probably require testing on either block samples or very high quality large diameter tube samples.

As previously discussed, the Lower Glaciolacustrine Unit was subdivided into two subunits, namely 3A and 3B. The grain

FIGURE 6-5: VARIATION OF SHEAR STRENGTH WITH THE ANGLE OF TESTING, UNIT 3



LEGEND

- Unconfined Compression Test
- Quick Triaxial Test
- After Lo and Milligan, 1967

TABLE 6-4: SUMMARY OF LABORATORY RESULTS, LOWER GLACIOLACUSTRINE UNIT

SUBSIDIARY No.	B.H. No.	SAMPLE No.	DEPTH (m)		WATER CONTENT (%)	CLAY (%)	LIMITS			A		TOTAL UNIT WEIGHT (kN/m3)	DRY UNIT WEIGHT (kN/m3)	Gs	n (%)	e	Sr (%)	CONSOLIDATION DATA			UNDRAINED SHEAR STRENGTH			EFFECTIVE SHEAR STRENGTH								
			FROM	TO			w (%)	wp (%)	PI (%)	PI (%)	ec (kPa)							p'c (kPa)	K (m/s)	Cu (kPa) residual	Strain (%)	Test Type	St	Cu (kPa)	phi' (Degrees)	c' (kPa)	Test Type					
85-	8-2	22	23.77	24.38	31.8	52.3	42	22	20	0.38	19.04	14.45			47	0.89	100				13	0	0 deg									
	8-2	22	23.77	24.38	31.8																13	0	0 deg									
	8-2	22	23.77	24.38	27.6																											
	3A	8-2	19	24.4	25	26.3	46.5	32	15	17	0.41	20.06	15.28																			
	3A	3-2	19	24.4	25	27.4		37	21	16		19.68	15.6																			
	3A	3-2	19	24.4	25	31.8					14.25	10.81																				
	3A	3-2	19	24.4	25	26.8					18.72	14.76																				
	3A	5-2	26	24.84	25.45	32.7		41	22	19		19.19	14.47																			
	3A	5-2	26	24.84	25.45	32.7																										
	3A	5-2	26	24.84	25.45	35		55	32	23		18.67																				
	3A	10-2	28	29.4	30	35	57.4	45	25	24	0.42	19.6																				
	3A	12-2	27	29.4	30	37.7	48.7	38	19	19		19.21	14.63																			
	3B	5-2	30	29.41	30.02	31.3																										
	3B	5-2	30	29.41	30.02	31.3																										
	3B	5-2	30	29.41	30.02	42		41	23	18		18.24																				
	3B	1-2	30	29.41	30.02	40.2																										
	3B	1-2	30	29.41	30.02																											
	3B	1-2	30	29.41	30.02	33.1	67.5	42	18	24	0.36	18.7	14.05																			
	3B	1-2	30	29.41	30.02	41.8						17.82																				
	3B	1-2	30	29.41	30.02	39.6						18.13	12.99																			
	3B	8-2	27	29.87	30.48	32.9	50.5																									

size distribution of subunits 3A and 3B are shown in Figures E2-6 and E2-7, Appendix E2, respectively. A summary of the laboratory tests carried out on numerous samples from the Lower Glaciolacustrine Unit are tabulated in Table 6-4.

6.2.3.1 Subunit 3A

The upper 7 m of the Lower Glaciolacustrine consists of a medium to high plasticity, silt and clay to a clay and silt, with a trace of sand. The material, with an average water content of about 29% and is about 3 to 10% wetter than its plastic limit (Figure 6-1).

As indicated in Table 6-4, vertically oriented undrained shear strength tests were carried out on samples from subunit 3A values ranging from 51 to 78 kPa. The stratum is inferred to be of stiff consistency.

One set of direct shear tests and one set of triaxial tests were performed on samples from subunit 3A. As shown in Table 6-4, the tests yielded peak ϕ' values of 26 and 20 degrees with corresponding peak c' values of 10 and 0 kPa, respectively. The lower peak c' values indicate the reduced overconsolidation of the subunit. Results of the direct shear testing indicated a residual ϕ value of 19 degrees and a residual c value of 0 degrees.

6.2.3.2 Subunit 3B

Underlying subunit 3A is an approximate 4 m thick layer of laminated medium to high plasticity (based on laboratory test results and visual observations), silt and clay to a silty clay, with a trace sand. The most pronounced differences between subunits 3A and 3B are the increased average moisture content and Plasticity Index within subunit 3B.

As indicated in Figure 6-1 and Table 6-4, the undrained shear strengths of vertical samples from subunit 3B range from 33 to 83 kPa indicate a firm to stiff consistency.

Results of one set of direct shear tests indicated a peak ϕ' of 18.5 degrees and a peak c' of 0 kPa. The negligible effective cohesion within the Lower Glaciolacustrine Unit is a reflection of the slightly overconsolidated to normally consolidated nature of the stratum. A slightly lower residual ϕ value of 17 degrees was determined from the direct shear test.

6.2.4 LOWER TILL UNIT

The Lower Till is the basal soil unit underlying the study area. In texture the Lower Till is a well graded mixture of gravel, silt and sand as shown in Figure E2-8, Appendix E2. Standard Penetration Test resistance (SPT) "N" values indicate the Lower Till is in a very dense to compact condition. Based on its physical characteristics as determined by SPT results and stratigraphic position, the top surface of the Lower Till is considered to be the base of all potential slope stability failure surfaces so no detailed geotechnical laboratory tests were carried out for the Phase 4B program.

6.3 BEDROCK

Dolostone bedrock was encountered below the Preferred Site at depths averaging 35.5 m below existing grade. A more detailed discussion of depth to bedrock is presented in Section 2.0 of this report.

In general, the upper 3 m of the bedrock is fractured as indicated by an average RQD of 47%. Below this depth the average RQD increases to about 84% inferring an unfractured rock.

7-1

7.0 REFERENCES

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SECTION 8.0

GLOSSARY OF TERMS

SECTION 8.0 GLOSSARY OF TERMS

Definitions for selected terms used in this report are provided in this section.

Sources, where applicable, are provided at the rear of this section and are referenced by the bracketed number following each definition.

Some definitions are altered slightly to reflect usage in this report and may not reflect the wide range of meanings provided in the source.

8.0 GLOSSARY OF TERMS

Advection

The process by which solutes are transported by the bulk motion of the flowing ground water. (10)

Aquifer

A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs. (2)

Aquitard

Generally used to describe the less-permeable beds in a stratigraphic sequence. These beds may be permeable enough to transmit water in quantities that are significant in the study of regional ground water flow, but their permeability is not sufficient to allow the completion of production wells within them. (10)

Atterberg Limits

In a sediment, the water-content boundaries between the semi-liquid and plastic states (known as the "liquid limit") and between the plastic and semi-solid states (known as the "plastic limit"). (1)

Average Linear Ground Water Velocity ($\bar{v}$)

The volumetric flux (Q) which passes through the actual cross-sectional area through which flow occurs. The equation for average linear ground water velocity is $\bar{v} = Q/(A_n)$ where A is the cross-sectional area and n is the porosity. The usual units are m/s or m/a. (10)

Capillary Zone

Also called the capillary fringe or tension-saturated zone; the zone directly above the water table in which the pore spaces are fully saturated, but pressure is less than atmospheric. (10)

Carbon-13

This is a naturally occurring stable isotope of carbon. Stable means it is not radioactive. The average terrestrial abundance of carbon-13 is approximately 1.11% of the total carbon.

Carbon-14

This is a radioactive isotope of carbon with a half life of approximately 5730 years. The steady-state concentration of carbon-14 in the atmosphere is about one carbon-14 atom in 10 atoms of ordinary carbon. (10)

Cohesion

Shear strength of a soil or rock not related to interparticle friction. (1)

Compaction Test

A laboratory compacting procedure to determine the optimum water content at which a soil can be compacted so as to yield the maximum density (dry unit weight). The method involves placing (in a specified manner) a soil sample at a known water content in a mold of given dimensions subjecting it to a compactive effort of controlled magnitude, and determining the resulting unit weight. The procedure is repeated for various water contents sufficient to establish a relation between water content and unit weight. The maximum dry density for a given compactive effort will usually produce a sample whose saturated strength is near maximum. (1)

Confining Bed (Layer)

A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (1)

Consolidation

The gradual reduction in volume and increase in density of a soil mass in response to increased load or effective compressive stress; e.g. the squeezing of fluids from pore spaces. (1)

Consolidated - Undrained Test (consolidated quick test)

A soil test in which essentially complete consolidation under the vertical load (in a direct shear test) or under the confining pressure (in a triaxial test) is followed by a shear at constant water content. (11)

Darcy's Law

For the velocity of percolation of water in saturated soil:
 $\text{Velocity} = \text{coefficient of permeability} \times \text{hydraulic gradient}$.
 (4) (hydraulic conductivity is used in place of coefficient of permeability in this report).

Diffusion

Diffusion in solutions is the process whereby ionic or molecular constituents move under the influence of their kinetic activity in the direction of their concentration gradient. Diffusion can occur in the absence of any bulk hydraulic movement of the solution. If the solution is flowing, diffusion is a mechanism, along with mechanical dispersion, that causes mixing of ionic or molecular constituents. (10)

Dispersion

During flow through porous media, substances dissolved in the ground water (known as solutes), tend to spread out from the path they would be expected to follow based only on the ground water flow path and velocity. This spreading phenomenon is called hydrodynamic dispersion. It causes dilution of the solute. It occurs because of mechanical mixing during flow through the soil pores and because of molecular diffusion. (10)

Direct Shear Test

A shear test in which soil or rock under an applied normal load is stressed to failure by moving one section of the sample or sample container (shear box) relative to the other section. (11)

Discharge

The removal of water from the saturated zone across the water table surface, together with the associated flow toward the water table within the saturated zone. (10)

Dolostone

A term proposed for the sedimentary rock dolomite, in order to avoid confusion with the mineral of the same name. (1)

Dolomite is defined as "a carbonate sedimentary rock of which more than 50% by weight or by areal percentages under the microscope consists of the mineral dolomite, or a variety of limestone or marble rich in magnesium carbonate". (1)

Deuterium

This is a naturally occurring stable isotope of hydrogen. Stable means it is not radioactive. Deuterium comprises approximately 0.016% of the hydrogen in sea water.

Drawdown

The lowering of the water level in a well as a result of withdrawal. (1)

Drift

A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. (1)

Dry Unit Weight

The unit weight of soil solids per unit of total volume of soil mass. (5)

Evaporite

A nonclastic sedimentary rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include: gypsum, anhydrite, rock salt, primary dolomite, and various nitrates and borates. (3)

Evapotranspiration

Water losses to the atmosphere through the combined processes of evaporation from open water bodies, evaporation from soil surfaces and transpiration from the soil by plants. (10)

Fracture Porosity

Porosity which is due to fractures. This is a particular type of secondary porosity (see below).

Geophone

A seismic detector that produces a voltage proportional to the displacement, velocity, or acceleration of ground motion, within a limited frequency range. (1)

Geophysics

Study of Earth by quantitative physical methods (1).

Geometric Mean

The n th root of the product of the values of n positive numbers; the antilogarithm of the mean of the logarithms of individual values. (1)

Geotechnical, Geotechnics

Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems. (1)

Glacial Lake

A lake fed predominantly by glacial meltwater or a lake in a depression in part closed by glacial ice. Includes lakes not directly adjacent to the glacier and lakes lying against or on a glacier, and fed mainly by waters derived from the melting of a glacier. (2)

Glaciofluvial

Pertaining to streams flowing from glaciers or to the deposits made by the streams. (2)

Glaciolacustrine

Pertaining to or characterized by glacial and lacustrine (lake) conditions. Material deposited in lakes affected by glacier ice, or deposited by meltwater flowing directly from glaciers into a lake. (2)

Ground Water

Subsurface water occurring below the water table (phreatic surface) in the saturated zone in which all pores are filled with water under hydrostatic pressure. This contrasts with subsurface water above the water table, which is referred to as soil moisture. (2)

Ground Water Flux

Also called Darcy flux or specific discharge, see specific discharge.

Grout

A cement slurry of high water content, fluid enough to be poured or injected into spaces and thereby fill or seal them.(1)

Gypsum stringer

A "stringer" is defined in (1) as a thin sedimentary bed. In this case it is composed of the mineral gypsum.

Hardness (Water)

A property of water causing formation of an insoluble residue when the water is used with soap, and forming a scale in vessels in which water has been allowed to evaporate. It is primarily due to the presence of ions of calcium and magnesium, but also to ions of other alkali metals, other metals (e.g. iron), and even hydrogen. Hardness of water is generally expressed as parts per million as CaCO_3 (40 ppm Ca produces a hardness of 100 ppm as CaCO_3); also as milligrams per litre, and is the combination of carbonate hardness and noncarbonate hardness. (1)

Hazardous Waste

Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Hydraulic Gradient

The rate of change of total head per unit of distance of flow at a given point and in a given direction. (1)

Hydraulic Head

The height of the free surface of a body of water above a given subsurface point. (1)

Hydraulic Conductivity

The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3)

Hydrogeology

The science that deals with subsurface waters and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit

A term proposed by Maxey (1964, p.126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1) (used here for soil and rock).

Infiltration

The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock. (1)

Intergranular Porosity (also "Primary Porosity")

Porosity which is due to the soil or rock matrix. (10)

Internal friction (shear resistance)(FL^{-2})

The portion of the shearing strength of a soil or rock indicated by the terms $p \tan$ in Coulomb's equation $s = c + p \tan$. It is usually considered to be due to the interlocking of the soil or rock grains and the resistance to sliding between the grains. (11)

Isotope

One of two or more species of the same chemical element; i.e. having the same number of protons in the nucleus, but differing from one another by having a different number of neutrons. The isotopes of an element have slightly different physical and chemical properties, owing to their mass differences, by which they can be separated. (1)

Lamina

The thinnest recognizable unit layer of original deposition in a sediment or sedimentary rock, differing from other layers in colour, composition, or particle size; specifically such

a sedimentary layer less than 1 cm in thickness (commonly 0.05 - 1.00 mm thick). (1)

Log

A continuous record as a function of depth, usually graphic and plotted to scale on a narrow paper strip, of observations made on the rocks and fluids of the geologic section exposed in a well bore. (1) (used here for soil and rock).

Monitor Recovery

The change in water level in a piezometer toward static conditions as a function of time. This information can be analysed to assess the hydraulic conductivity of the screened interval.

Moraine

Accumulation of glacial material (mainly till) deposited by glaciers. (2)

Oxygen-18

This is a naturally occurring stable isotope of oxygen. Stable means it is not radioactive. Oxygen-18 comprises approximately 0.20% of the oxygen in sea water.

Packer Testing

Hydraulic testing performed in boreholes whereby a pair of inflatable seals (packers) are used to isolate the interval of the borehole to be tested. Typical tests include slug tests and hydraulic head measurements.

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders	(Pebble)	>200
Cobbles		60-200
Gravel		2-60
Sand	Coarse	0.6-2
	Medium	0.2-0.6
	Fine	0.06-0.2
Silt		0.002-0.06
Clay		<0.002

Permeability

The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Piezometer

A pipe or tube in the ground which allows for the determination of water level elevation. It is usually constructed with a slotted pipe or screen at the bottom that permits inflow of water but not geologic materials; it is sealed above the screened section, and it is open to the atmosphere at the top. (10)

Pneumatic Piezometer

A particular type of piezometer (see above) whereby air pressure is used to measure the water level rather than direct measurement.

Porosity

The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for fluid transmission (3).

Pore Water Pressure

Stress transmitted through the pore water. (5)

Preconsolidation Pressure

The greatest effective stress to which a soil or sediment has been subjected; the pressure exerted on unconsolidated sediment by present or former overlying material, or by desiccation of a silt or clay, resulting in compaction. (1)

Pumping Test

A hydraulic test whereby ground water is pumped from a borehole and ground water levels in the pumping wells and nearby observation wells are monitored. The information obtained from the pump test can be analysed to assess the transmissivity, specific storage and hydraulic conductivity of the formation.

Quaternary

The youngest period of the two geologic time divisions of the Cenozoic Era. The Quaternary is subdivided into the Pleistocene and Recent (or Holocene) Epochs. It comprises all geologic time and deposits from the end of the Tertiary (approximately 2 million years ago) until and including the present. (2)

Recharge

The entry into the saturated zone of water made available at the water table surface, together with the associated flow away from the water table within the saturated zone. (10)

Reflecting Horizon

A major layer of reflection (1)

Saturated

Said of the condition in which the interstices of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (1)

Seismic reflection

The return of a wave incident upon a surface to its original medium (1)

Seismic velocity

The rate of propagation of an elastic wave, usually measured in m/sec. (1)

Seismograph

An instrument that detects, magnifies and records vibrations. (1)

Shear Strength

The internal resistance offered to shear stress. It is measured by the maximum shear stress, based on original area of cross-section, that can be sustained without failure. (5)

Two extreme conditions may be recognized: drained conditions, under which the changes in stress are applied so slowly with respect to the ability of the soil to drain that no excess pore pressures develop, and undrained conditions, under which the stresses are changed so rapidly with respect to the ability of the soil to drain that no dissipation of pore pressure takes place. (7)

Secondary Porosity

Porosity which may be due to such phenomena as secondary chemical solution or fracturing (10).

Slug Test

A method of determining in situ hydraulic conductivity in a single piezometer by causing an instantaneous change in the water level by adding or displacing a known volume of water. (10)

Solute

Dissolved ions and molecules in the ground water. (10)

Specific Discharge (v)

The quantity of ground water flowing through a porous media per unit area perpendicular to the flow direction. the equation for specific discharge is $v = Q/A$ where Q is the volumetric flux and A is the area perpendicular to flow. The usual units are m/s or m/a. (10)

Specific gravity

The ratio of the weight in air of a given volume of solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature. (11)

Split Spoon Sampler

Sampling spoons for exploratory borings commonly consist of a pipe with an inside diameter of about 35 mm and an outside diameter of about 51 mm. The pipe is split lengthwise. Consequently, the sampler is called a split spoon. While the sample is being taken, the two halves of the spoon are held together at the ends by short pieces of threaded pipe. One piece serves to couple the spoon to the wash pipe. The other, which has been sharpened, serves as the cutting edge while the spoon is driven into the soil. Exact dimensions are designated in ASTM D1586-67. (7)

Standpipe

A particular type of piezometer (see above) whereby the screened interval straddles the water table elevation.

Static (Water) Level

That water level of a well that is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit

A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Till

An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Triaxial Compression Test

A test in which a cylindrical specimen of soil encased in an impervious membrane is subjected to a confining pressure and then loaded axially to failure. (1)

Tritium

This is a radioactive isotope of hydrogen with a half life of approximately 12.3 years. (10)

Unconfined Compression Test

A special condition of a "triaxial compression test" in which no confining pressure is applied. (1)

Unconsolidated - Undrained Test (quick test)

A soil test in which the water content of the test specimen remains practically unchanged during the application of the confining pressure and the additional axial (or shearing) force. (1)

Vane Test

A test to measure the shear strength of fine-grained cohesive soils and other soft deposits. A rod with four flat radial blades, or vanes, projecting at 90-degree intervals is forced into the soil and rotated; the torque required to rotate the rod is a measure of the material's shear strength. (1)

Vug

A small cavity in a vein or rock, usually lined with crystals of a different mineral composition from the enclosing rock. (1)

Water budget (Also: water balance, hydrologic budget)

An accounting of the inflow to, outflow from, and storage in a hydrologic unit such as a drainage basin, aquifer, soil zone, lake or reservoir; the relationship between evaporation, precipitation, runoff and the change in water storage, expressed by the hydrologic equation. (1)

Water Table

A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering

The destructive process or group of processes by which Earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical desintegration and chemical decomposition of rock that produce an in situ mantle of waste and prepare sediments for transportation. (1)

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Volume

2

Final report

OWMC

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Waste Management
Corporation**

A provincial crown corporation



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Lee
Associates
Limited**

SITE ASSESSMENT
PHASE 4B:
GEOLOGY, HYDROGEOLOGY AND
GEOTECHNICS, BASELINE CONDITIONS
VOLUME 2
APPENDICES A THROUGH D

Prepared for
The Ontario Waste Management Corporation

Submitted By

Gartner Lee Limited

October, 1987



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Mr. J.G. Micak
Manager, Environmental Projects
Ontario Waste Management Corporation
2 Bloor Street West, 11th Floor
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Attention: Mr. D.F. Chollak,
Environmental Planner

Dear Sirs:

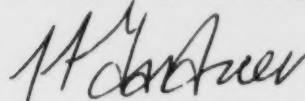
Re: Site Assessment Phase 4B: Geology,
Hydrogeology and Geotechnics
- Baseline Conditions

We are pleased to provide you with Volume 2 of the above noted three-volume report. This report is one of six Phase 4B companion reports describing baseline conditions, hydrogeologic inputs to landfill design, geotechnical inputs to facilities design, potential impacts of the landfill on ground water, potential impacts of the central operation area on ground water and ground water management strategies.

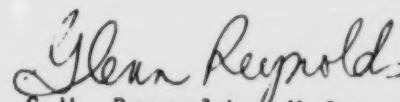
We thank you for this opportunity to be of service. Should you have any questions please do not hesitate to call.

Yours very truly,

GARTNER LEE LIMITED

for 
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Project Director

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G.W. Reynolds, M.Sc.,
Senior Hydrogeologist,
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A-1

APPENDIX A

DRILLING, GEOLOGIC SAMPLING, INSTRUMENTATION
AND HYDRAULIC TESTING PROTOCOLS

APPENDIX A

DRILLING, GEOLOGIC SAMPLING, INSTRUMENTATION AND HYDRAULIC TESTING PROTOCOLS

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A1 DRILLING AND GEOLOGIC SAMPLING

A1.1 INTRODUCTION

This Appendix describes the drilling and geologic sampling practices used to collect field data during the Phase 4B geoscience program. The major drilling and sampling activities are shown in Figure A1-1. For the most part procedures for the drilling and sampling operations, as described in the Phase 4B Protocols document (GLAL, 1986a), were adhered to throughout the drilling program. The protocol document served as a procedures manual for the field staff during the drilling program. Minor modifications to the drilling and sampling protocols were made in the field to accommodate actual field conditions. A summary of the protocol procedures (GLAL, 1986a) are discussed herein.

Details of monitor design and installation are described in Appendix A2 of this report.

Daily liaison with the Gartner Lee Markham office was maintained through a temporary field office at the site.

A1.2 DRILL SITE IDENTIFICATION

A1.2.1 PRELIMINARY DATA ANALYSIS

A preliminary review of existing water well and test hole data was completed to establish a basis for the selection of tentative drill locations. Criteria used included the following:

- o the distribution of existing test holes and water wells;
- o seismic survey;

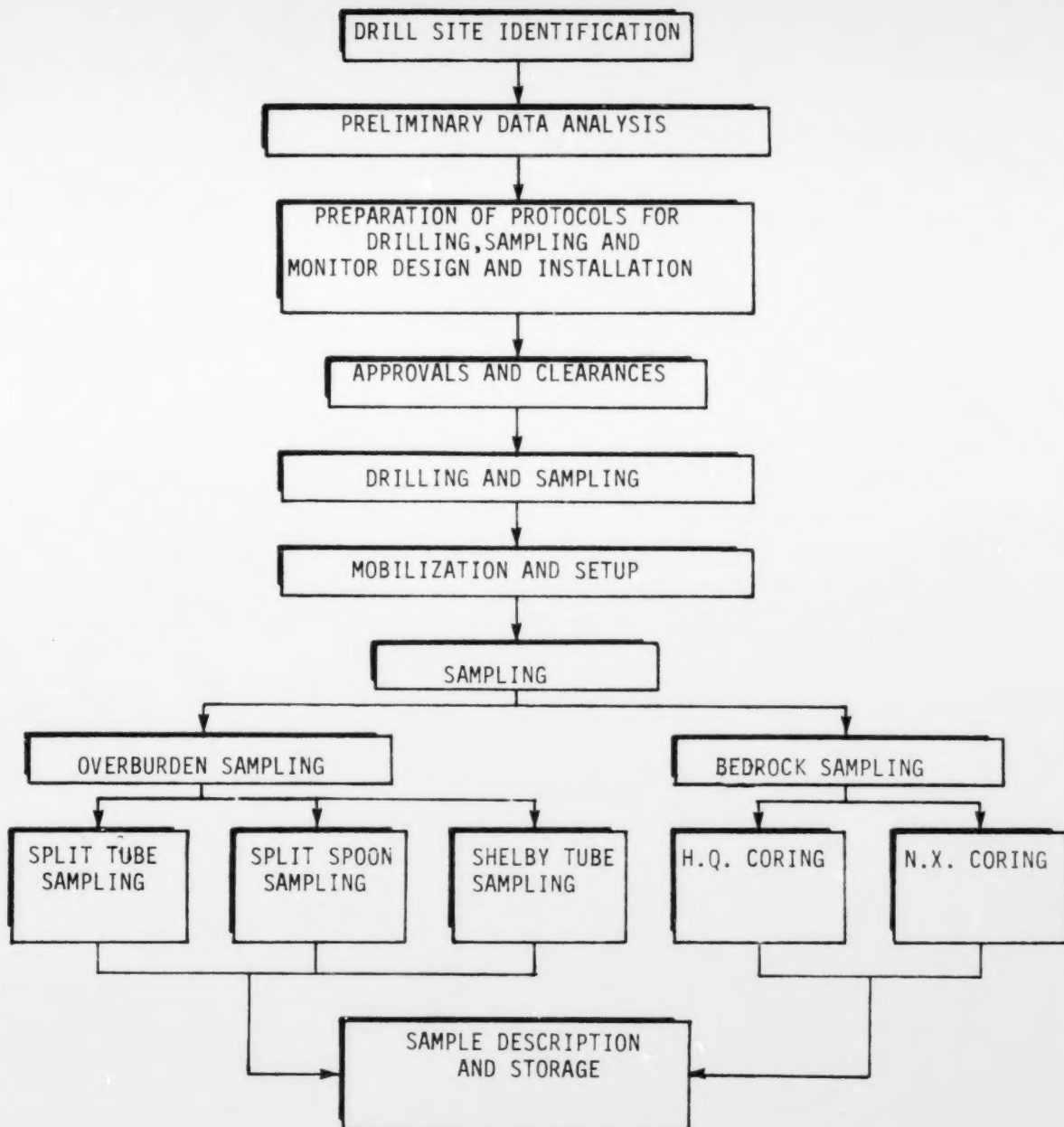


FIGURE AI-1

DRILLING & GEOLOGIC SAMPLING ACTIVITIES

- the continuity of existing data; and
- anomalous or unusual site conditions.

Monitor details including the type of installation, location and distribution of monitors are provided in Appendix A2.

A1.2.2 PROTOCOLS

Detailed protocols which described the drilling, sampling and monitor design and installation practices to be used during the Phase 4B geoscience program were developed following a preliminary review of existing data. Field data requirements were identified for major program components including geophysics, geology, geotechnics, hydrogeology, and geochemistry. These requirements were incorporated into the overall drilling and sampling program. Soil samples taken from different boreholes were dedicated to different program components; although, where possible, samples were shared between programs. The various program components are outlined in the Phase 4B, Geoscience Work Plan (GLAL, 1986b).

A1.2.3 APPROVALS AND CLEARANCES

Preliminary sketches were completed showing each drilling location and the proposed borehole arrangement at each location. Access and work area requirements were identified for each drilling location from a field visit.

All of the drilling locations, both on and off-site, were located on private property. Access and lease agreements were arranged for each drilling location. Negotiations for these agreements were completed by the Ontario Ministry of Government Services on behalf of the Ontario Waste Management Corporation.

Culverts were installed at four locations around the site to provide safe access across steep ditches. Arrangements were made directly with the Township of West Lincoln and the Ontario Ministry of Transportation and Communications for culvert installations. One culvert was required on-site to access interior drilling locations. The design specifications, installation and inspection of the culvert were carried out by M.M. Dillon Limited.

Buried services were located in the vicinity of each drilling location. Local utilities including gas, telephone, and other municipal services were cleared prior to the drilling program.

A1.3 DRILLING AND SAMPLING

A1.3.1 DRILLING EQUIPMENT AND SETUP

All Terrain Drilling Limited was retained to provide drilling services. The drilling equipment included one truck-mounted CME 75, one truck-mounted CME 55, and one track-mounted CME 75 auger drilling rig. Each rig was equipped to drill and sample both overburden and bedrock. Each rig was staffed by a two-man crew. Two additional helpers provided support services for all three rigs. Each drill rig was supervised by a Gartner Lee geologist. Drilling operations were directed from a central field office temporarily set up at the site.

The drilling operations commenced November 14, 1985 and were completed March 12, 1986. The winter operations required a heated space for logging and storing soil and bedrock samples. Heated trailers were provided at each drill rig and a heated storage space was constructed at the central field office. A record of drilling activities for each drill rig was recorded daily on Daily Activity Log forms (Figure A1-2).

A-9

[illegible]

CONTRACTOR QUANTITIES: By _____ (DC) By _____ (GLAL)

1) _____ 4) _____ 7) _____

2) _____ 5) _____ 8) _____

3) _____ 6) _____ 9) _____

VISITORS: _____

OTHER: _____

DATE: _____ BY: _____ GLAL

The drill rigs were set up in accordance with standard drilling practices and in a manner that allowed the safe and efficient operation of the equipment. A safety corridor was roped off around the drill rig to limit access to the rigs. Access to the safety corridor was restricted to individuals with proper safety equipment which included steel-toed boots and a hard hat. A record was kept on a Visitor Record form (Figure A1-3) of all visitors to the field office and drill sites as well as persons entering the safety corridor.

Soil and rock samples were accessible to the general public for viewing and/or photographing as the samples were being logged by the on-site geologists. Field descriptions were recorded on Field Borehole Log forms (Figure A1-4). Samples were subsequently sealed in PVC split tubing sample containers or core boxes, labelled, and placed temporarily in the heated storage area. Samples were retrieved from the storage area for re-examination and final logging by the senior GLAL geologist. Each sample was resealed in the PVC split tubing after final logging, replaced in temporary storage and subsequently sent to the permanent storage facilities of the Ontario Geological Survey in Toronto.

A1.3.2 OVERBURDEN SAMPLING

The drilling program was designed to provide continuous samples from the ground surface to and including the upper few metres of the underlying bedrock at 12 on-site locations and four off-site locations. In addition two shallow stratigraphic boreholes were completed to investigate wet depressions on-site. Drilling locations are shown in Figure A1-5. A number of split spoon and shelly tube soil samples were also collected from various depths for hydrogeologic, geochemical and geotechnical testing from a

FIGURE A1-4

FIELD BOREHOLE LOG

PROJECT NAME

CLIENT

BOREHOLE TYPE

PROJECT NO.

DATE START _____ END _____

LOGGED BY

[illegible]

Drilling Locations

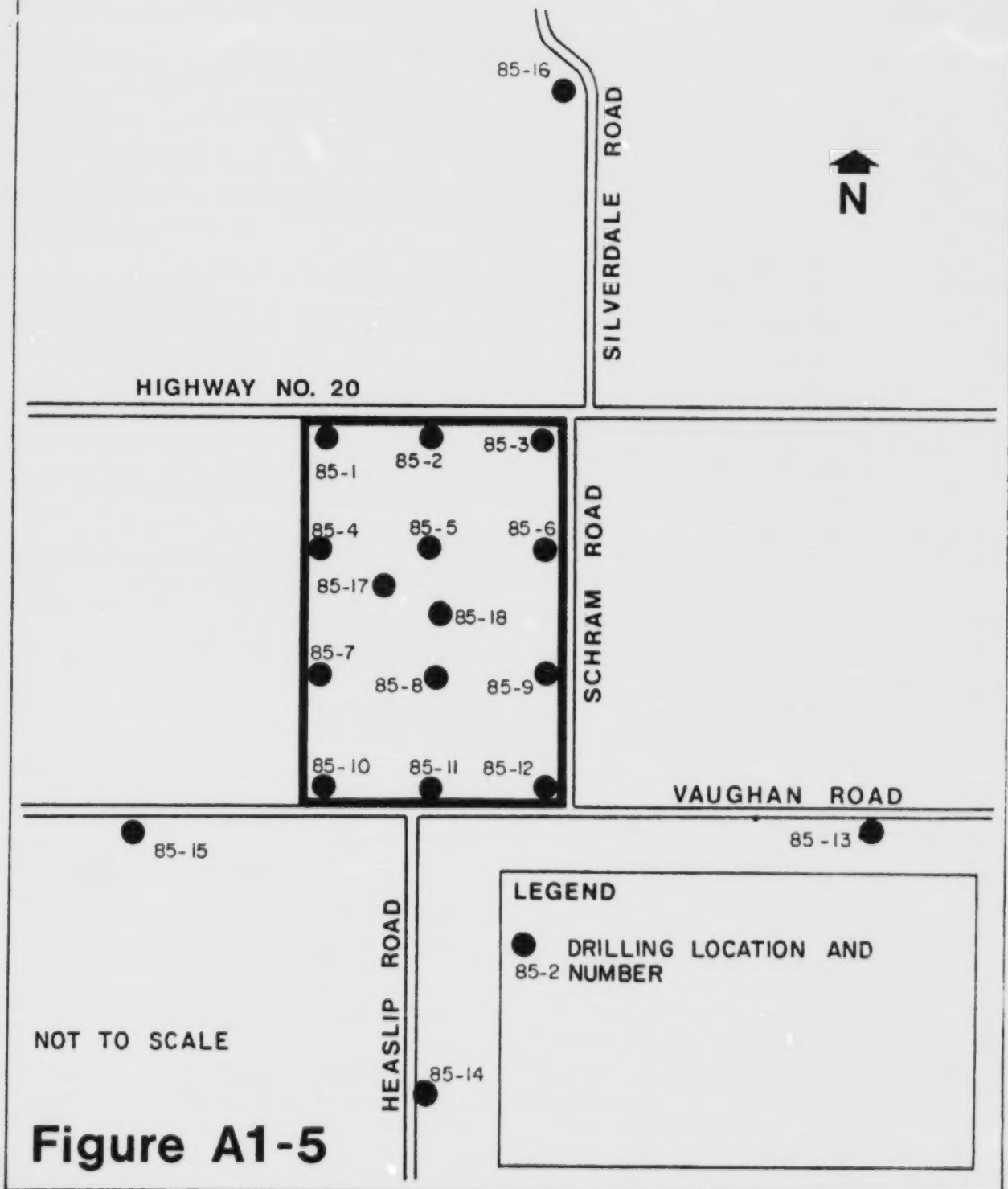


Figure A1-5

second borehole at each location. Sampling methods are in accordance with ASTM standards and are briefly described below.

Split tube sampling

Tube samples measuring approximately 89 mm in diameter by 1.52 m in length were taken continuously from ground level to the bed-rock surface. The tube sampler consisted of a split tube with a bevelled sampler tip. The split tube was threaded at both ends and fastened to the drill rods as shown in Figure A1-6. The sampler was advanced inside the hollow stem augers with the bevelled tip slightly ahead of the cutting edge of the augers. A split tube sample was obtained by advancing the sampler with the rotating augers. The augers and sampler were advanced at about 1.52 m intervals or until refusal, and the sampler was then withdrawn from the borehole. The soil sample was removed from the tube and the sampler wiped clean. Sample recovery for the tube samples was generally between 90 to 100% and was recorded in the field log. Difficult drilling conditions or large cobbles occasionally resulted in lower sample recovery.

The samples were placed in split PVC tubing, covered at each end with plastic caps and taped along the seams and at each end to minimize moisture loss.

Split tube sampling was carried out at each of the drilling locations.

Split spoon sampling

Split spoon samples were taken at 0.76 m intervals to 4.6 m and then at approximately 1.5 m intervals through the overburden at each of the on-site drilling locations. The split spoon measures 52 mm I.D. and 457 mm in length. Large diameter split spoon

Continuous Sampling With Split Tube Sampler

NOT TO SCALE

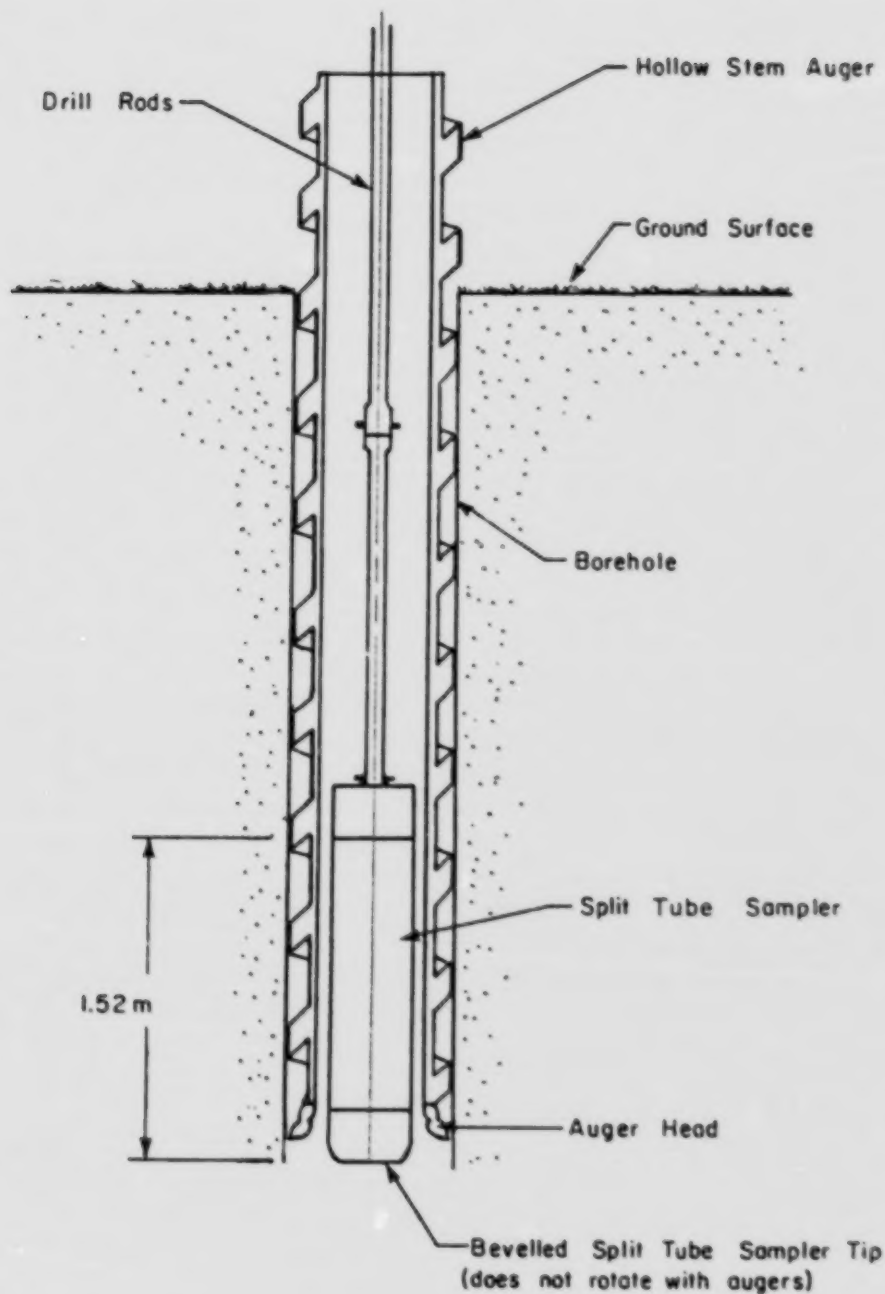


Figure A1-6

samples were taken from various depths at a number of locations on the site. These split spoons measured 102 mm I.D. and 610 mm in length.

The split spoon sampler was driven by dropping a 63.5 kg weight a distance of about 750 mm. The sampler was inserted inside the hollow stem augers in a similar fashion to the tube sampler. It was then driven into the soil below the bottom of the augers a distance of 460 mm or until refusal. The number of blows required to advance the sample for each interval of 150 mm was recorded in the field log. The split spoon was usually withdrawn when 50 or more blows were required to advance the sampler approximately 150 mm into the subsoil.

The large diameter split spoon was utilized in a similar fashion as the standard split spoon. It was driven into the soil a distance of 610 mm or refusal. The number of blows required to advance the sampler 150 mm was recorded on the field log.

At the four off-site borehole locations, split spoon sampling was carried out prior to the advancement of the split tube sampler or at 1.5 m intervals. Detailed sampling of the shallow weathered overburden (0.76 to 4.6 m) was not carried out because detailed geotechnical information was not required for the off-site locations.

Shelby tube sampling

Shelby tube samples were taken primarily for geotechnical testing. The sampler consists of a thin-walled steel sampling tube measuring 76 mm O.D. and 914 mm in length. Samples are obtained by pushing the sampling tube into the undisturbed material beneath the auger tip. The entire length of the Shelby tube is

pushed into the material or until refusal and is then withdrawn from the hole.

The lowermost portion of the Shelby tube sample was removed and placed in a plastic bag for storage. Both ends of the Shelby tubes were sealed in wax, covered with plastic caps and taped shut to minimize moisture loss. All samples were stored in a heated storage area prior to shipment to the laboratory.

Moisture tin samples

A small soil sample of approximately 100 grams was taken from the tip of each split spoon sample for laboratory determination of the soil moisture content. Soil moisture samples were placed in air tight tins immediately after they were taken from the split spoon samples. The moisture tin (sample) numbers were recorded on the field borehole logs. The samples were temporarily stored in the heated field facilities and shipped in batches to the Golder Associates (Eastern Canada) Limited laboratory for analysis.

Air rotary drilling

Air rotary drilling techniques were used to penetrate difficult soils that could not readily be drilled with hollow stem auger drilling methods. These techniques were used to drill through fractured rock at the bedrock surface. Air rotary drilling using a tricon drill bit was completed to about 3 m into bedrock for the construction of two 108 mm diameter pump wells at borehole locations 85-1 and 85-12. The air rotary drilling method utilized compressed air as a means of removing drill cuttings from the borehole. A special air filter installed on the air compressor removed trace amounts of oil from the compressed air while drilling. Water was added to the borehole where insufficient formation water was available to facilitate removal

of drill cuttings from the borehole. Water used in drilling was from the St. Catharines municipal system.

A1.3.3 BEDROCK SAMPLING

Diamond drill coring

Bedrock core samples were obtained at each of the drilling locations. Two sizes of drill core were obtained using HQ and NX size core barrels which provided 64 mm diameter and 54 mm diameter rock core, respectively. Procedures for diamond drilling are briefly described below.

The diamond drill bit and core barrel were positioned on the bedrock surface inside the hollow stem augers. Rock core was obtained by the cutting action of the rotating drill bit. Clean water was circulated in the borehole to remove cuttings from around the drill bit. About 3 m of HQ size rock core was obtained at locations 85-2 through 85-11 (Figure A1-5). At locations 85-1 and 85-12 about 30 m of NX size bedrock core was obtained. The NX size corehole was a requirement of the borehole packer testing program.

A1.3.4 SAMPLE DESCRIPTION AND STORAGE

Samples, taken from the boreholes, were described in the field and photographed. Sample descriptions were recorded on Field Borehole Log forms (Figure A1-4). These logs, together with the sample photos, form a permanent record of the samples collected.

The tube samples were transferred directly from the sampler into PVC tubular piping which was cut in half. The PVC pipe measures 89 mm inside diameter by 1.5 m long. One 'side' of the sample was scraped clean along its length with a knife or spatula to facilitate sample description. The PVC tubes were

sealed by covering the ends with plastic caps and taping the entire tube along the seams. Sample labels were affixed to each PVC tube.

The samples were stored temporarily in heated storage facilities until a sufficient number of samples were obtained for transport to permanent storage facilities in Toronto at the Ontario Geological Survey. Each shipment of samples was itemized on a Sample Packing List form (Figure A1-7). The contents of each shipment were also recorded on a Chain of Custody Record form (Figure A1-8) which showed the times and dates of sample transfer as well as the individuals involved in handling the samples.

Split spoon samples taken during the project were described in the field and moisture (moisture tin) samples taken from the base of the split spoon sampler were submitted to a laboratory for analysis. The moisture tin number was recorded on the Field Borehole Log form and on the Sample Packing List form. In cases where a split spoon sample was taken in place of the larger split tube samples, they were stored in labelled plastic bags and retained by Gartner Lee for future analysis. The top of each bedrock core segment was marked on both the core boxes and on the rock core itself with a felt marker.

Shelby tube soil samples were transferred to the Golder laboratory on a weekly basis from the heated field storage facilities. A Chain of Custody Record form accompanied each shipment of samples.

The soil and rock samples were re-examined by a senior Gartner Lee geologist at the central field office. The field descriptions were combined with the more detailed geologic log

A-20



Project No. _____

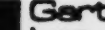
SAMPLE PACKING LIST

CLIENT: OWMC

BOX NO. ____ OF ____

[illegible]

A-21

 Gartner Lee Associates Limited	CHAIN OF CUSTODY RECORD
Project No.	
PROJECT: CLIENT :	BOREHOLE: SHEET __ OF __

[illegible]

prepared by the senior geologist to compile a final borehole log. All soil samples were resealed after examination.

A1.4 SITE CLEANUP

Disturbance to the area around the monitors was recorded in the form of photographs of each drilling location after completion of the drilling activities. A general site clean up was undertaken immediately following drilling. This was followed by a more comprehensive cleanup which involved the removal of small piles of drill cuttings around each monitor. Site levelling and seeding was undertaken later.

A2 MONITOR DESIGN AND INSTALLATION

A2.1 INTRODUCTION

Section A2 documents the protocols followed in the design and installation of the ground water monitors during the Phase 4B geoscience program. Included are details on:

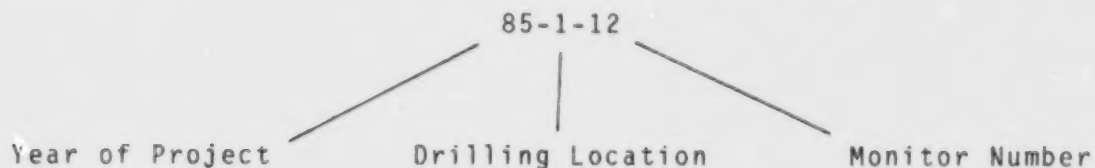
- the distribution of monitors (Section A2.2);
- the hydrogeologic monitors (Section A2.3); and,
- the geochemical monitors (Section A2.4).

A summary of monitor details is provided in Table F1-1, Appendix F.

A2.2 MONITOR DISTRIBUTION

A2.2.1 GENERAL

Ground water monitors have been installed at 16 of the 18 drilling locations shown in Figure A2-1. Monitors are labelled as shown in the following example:



Monitors were not installed at locations 17 and 18. Two relatively shallow stratigraphic test holes were completed at these two locations to investigate drainage swales on the site. Monitors were installed to varying depths and distributed across the site to provide cross-sections of representative

conditions. Four off-site locations were also drilled and monitored to establish conditions adjacent to or near the site.

A total of 121 ground water monitors were installed at 16 of the 18 drilling locations shown on Figure A2-1. These consist of:

- 75 water level monitors at 12 on-site locations;
- 38 water quality monitors at five on-site locations; and
- eight water level monitors at four off-site locations.

Included with the on-site water level monitors are two pump test wells and two observation wells at each of the pump test locations. All ground water monitors are fitted with protective steel casings with locking caps. The elevation of each monitor was surveyed with respect to geodetic datum.

The drilling locations are described below with respect to the intensity of the drilling as (a) normal, (b) composite, and (c) detailed.

A2.2.2 NORMAL DRILLING LOCATIONS (ON-SITE AND OFF-SITE)

Normal on-site drilling locations include only water level monitors, with monitors completed at different depths of the hydrostratigraphic units as shown schematically in Figure A2-2.

Normal off-site drilling locations consist of two water level monitors, one completed as a water table monitor and the other completed as a piezometer into the upper 3 m of the bedrock.

Drilling Locations And Types

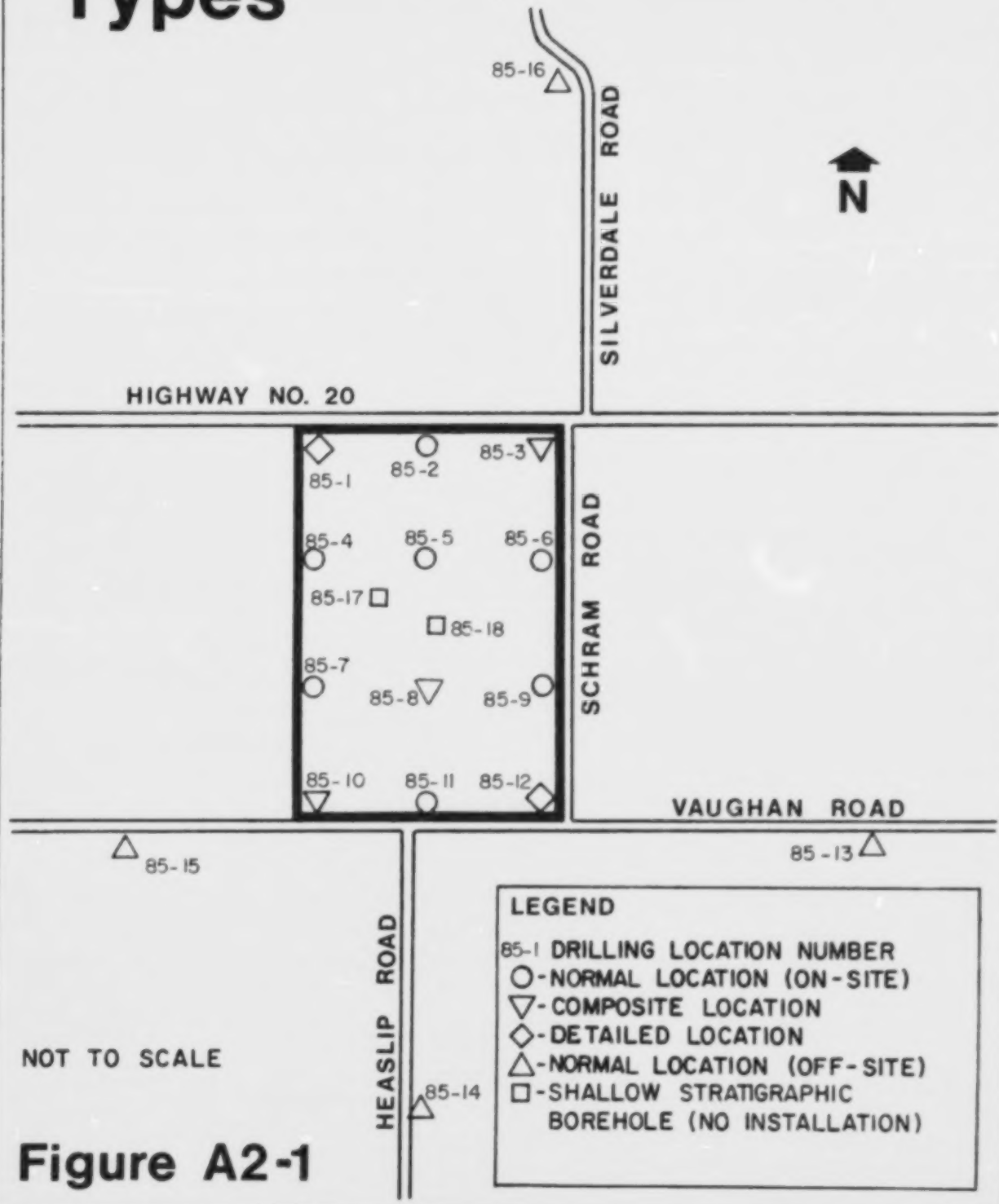
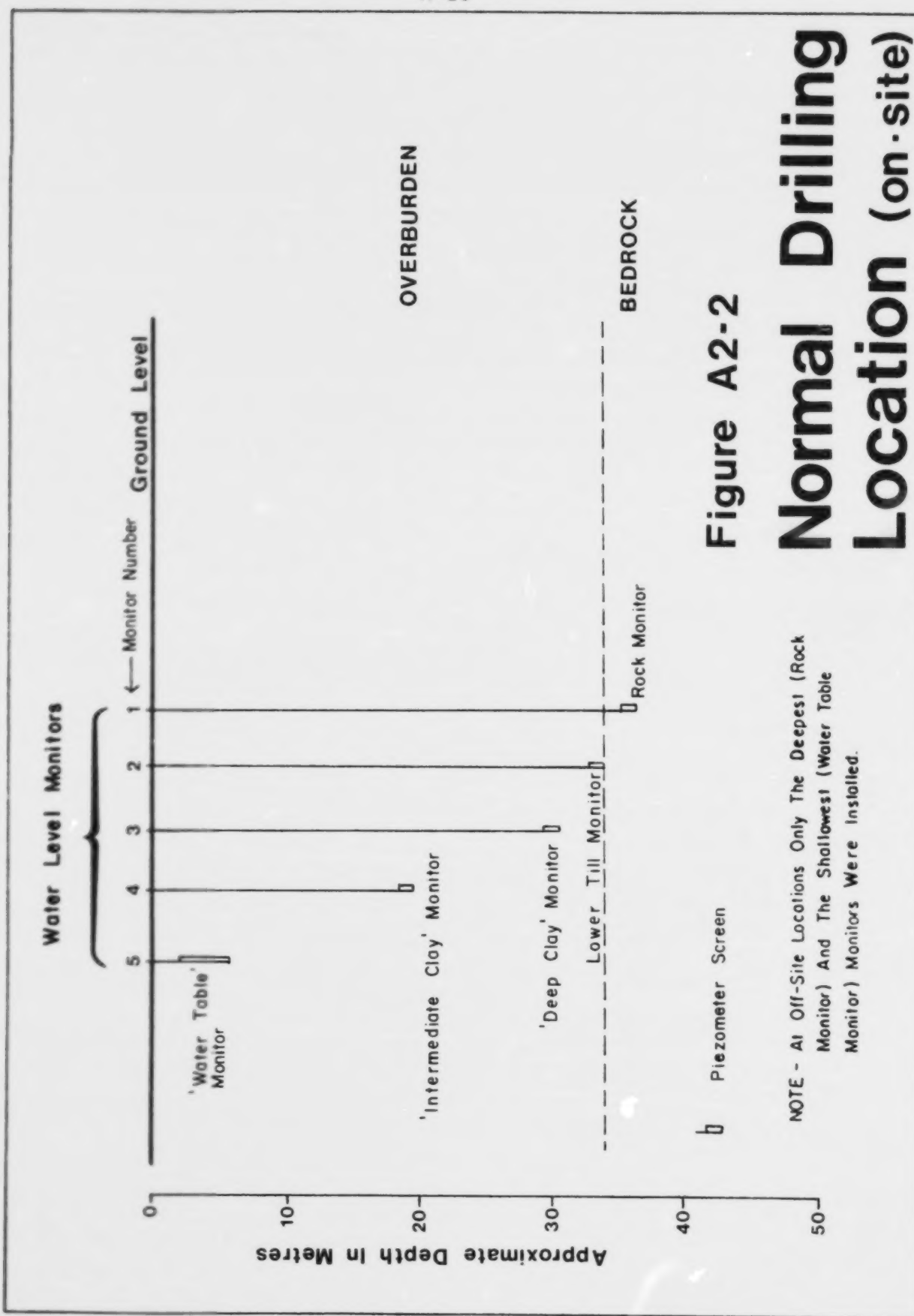


Figure A2-1



A2.2.3 COMPOSITE DRILLING LOCATION

There are three composite drilling locations as shown in Figure A2-1 (identified as 85-3, 85-8 and 85-10). These include both water level monitors and geochemistry monitors for a total of 11 monitors at each location (Figure A2-3). The water level monitors include two pneumatic piezometers, four standard piezometers in overburden, one standard piezometer in bedrock and one standpipe in the fractured silt and clay. There are three monitors constructed exclusively for water chemistry. The bedrock water level monitor serves as both a water level and water chemistry monitor. At drilling location 85-10 one extra shallow clay water level monitor was installed.

A2.2.4 DETAILED DRILLING LOCATION

There are two detailed drilling locations as shown in Figure A2-1, one at the northwest corner and one at the southeast corner of the site (identified as 85-1 and 85-12). These locations include all the components of the composite drilling locations plus a pump test well with bedrock observation well and a set of nine shallow overburden profile monitors. A total of 22 monitors were installed at each detailed drilling location. The arrangement of the monitors and the approximate depth of the installations are shown schematically in Figure A2-4.

A2.2.5 SHALLOW STRATIGRAPHIC DRILLING LOCATIONS

Two shallow stratigraphic drilling locations (85-17 and 85-18) are located on the site as shown in Figure A2-1. Continuous soil sampling was completed in one borehole at each of these locations and no monitor was installed. The borehole at each location was sampled in order to verify soil conditions beneath two perennially wet swales on the site.

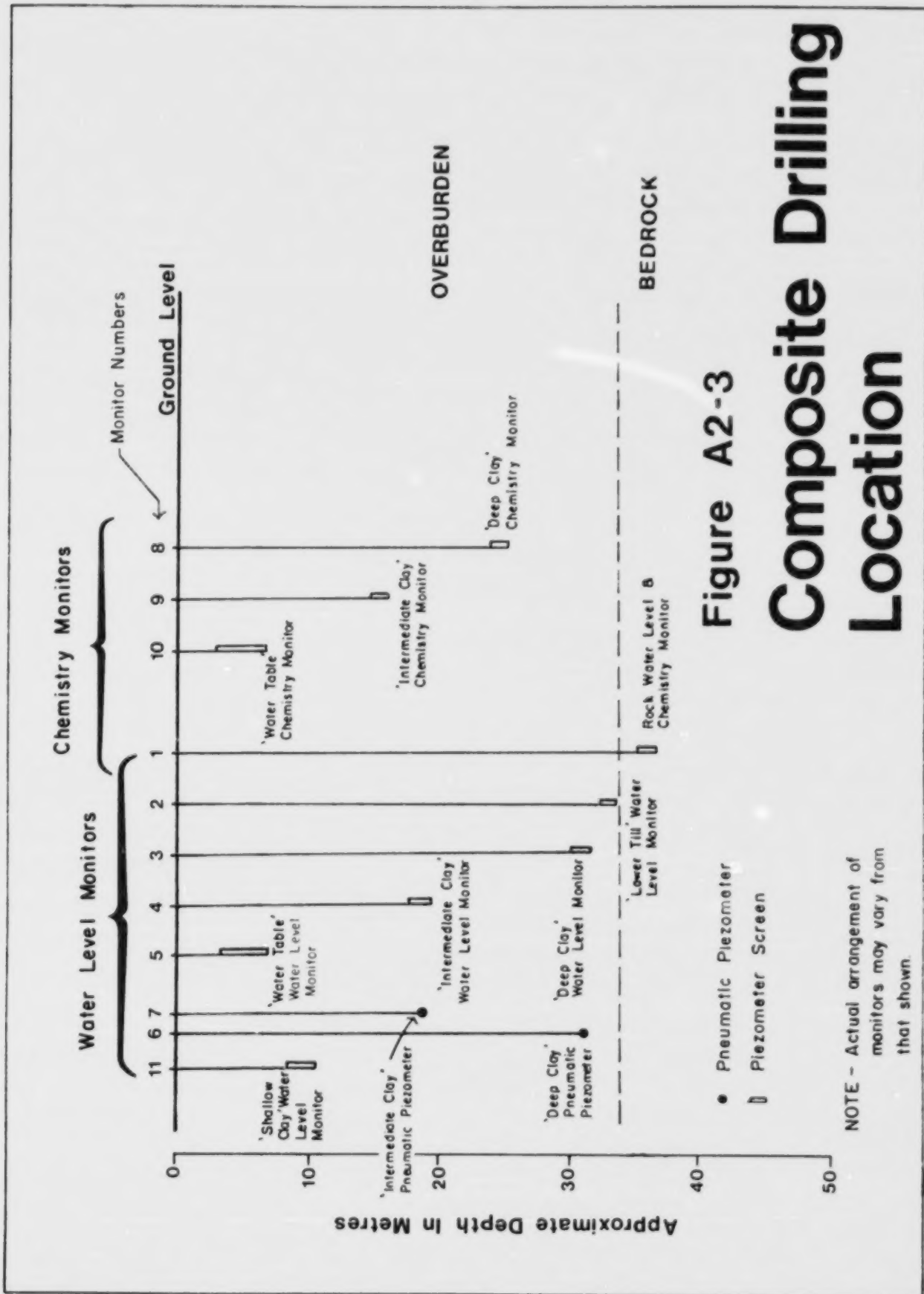
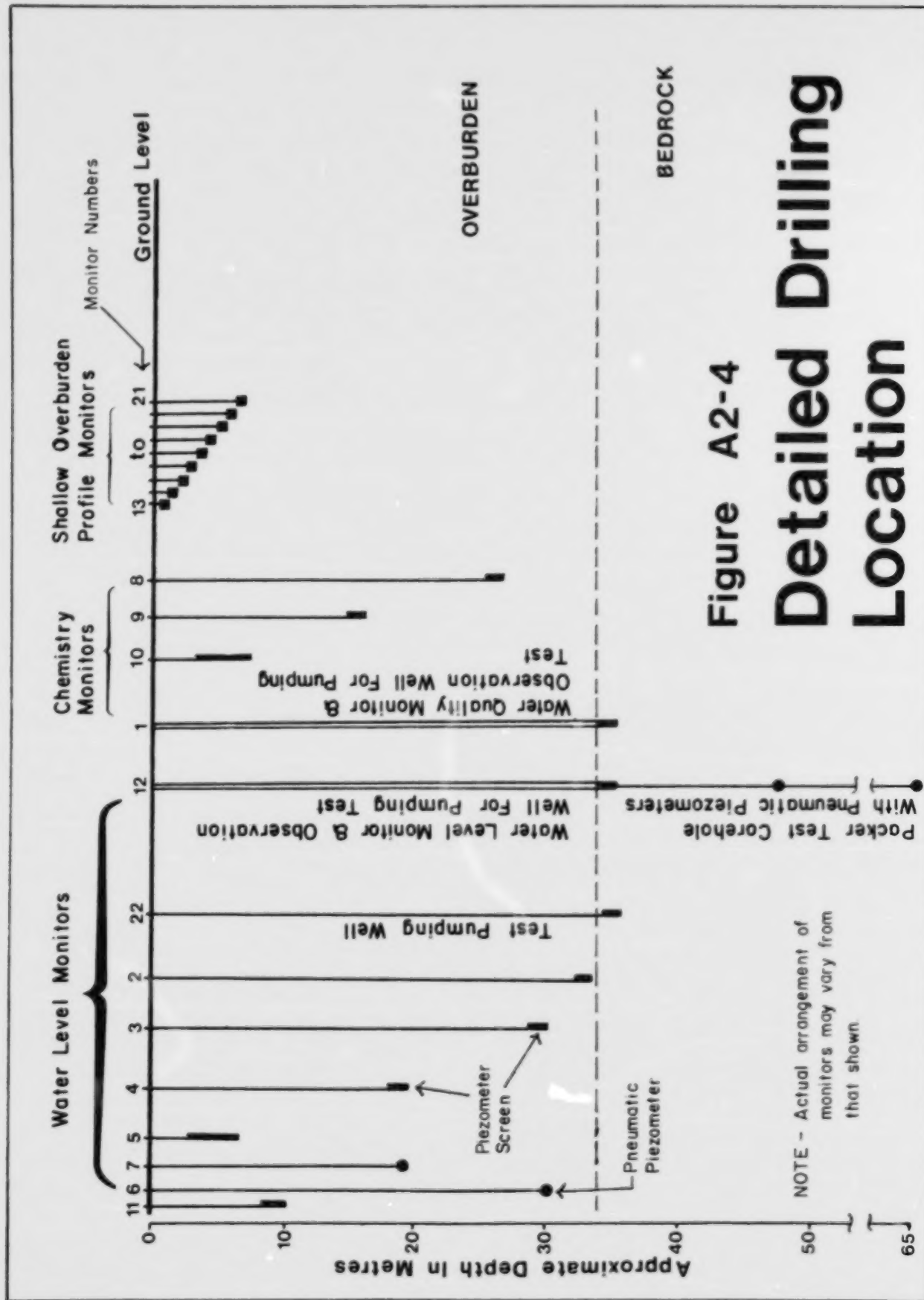


Figure A2-3

Composite Drilling Location



A2.3 HYDROGEOLOGIC MONITORS

Hydrogeologic monitors are designed to allow for the in situ testing of hydraulic conductivity and/or for the measurement of water levels or soil pore pressures. The monitors are completed to various depths below the surface to collect information on the bedrock and the overlying materials. Three basic types of hydrogeologic monitors were installed:

- standard piezometers;
- standpipes; and
- pneumatic piezometers.

A2.3.1 STANDARD PIEZOMETER

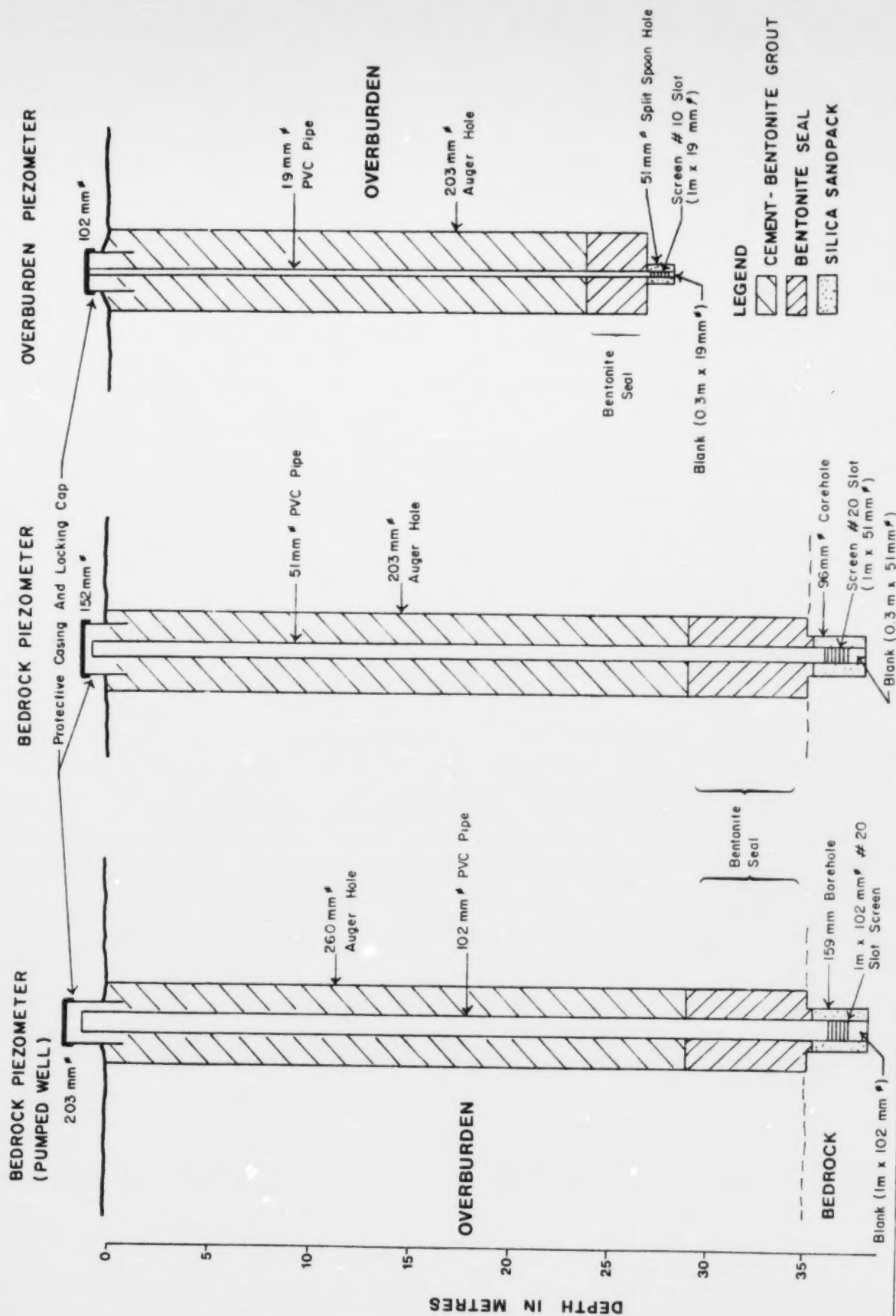
Construction details of standard piezometer installations, including the pump well, a typical bedrock piezometer, and a typical overburden piezometer are shown in Figure A2-5.

Standard piezometer ground water monitors are constructed of 102 mm and 51 mm diameter PVC for bedrock monitors and 19 mm diameter PVC for overburden monitors. The 102 mm monitors were installed at two locations for use as pump test wells. The 51 mm monitors are installed at each of the 12 on-site drilling locations and at the four off-site drilling locations. Two bedrock monitors are located near each of the pump test wells and serve as observation wells for the pump testing.

All PVC pipe is schedule 80, which was precut to 3 m lengths and equipped with threaded ends that provide flush joints. Each male threaded end was wrapped with teflon tape prior to joining the pipe lengths to ensure a water-tight seal.

Standard Piezometer Construction Details

Figure A2-5



Screens

Each monitor is equipped with either a screen or slotted interval of pipe. All screens and slotted intervals were supplied with threaded ends which provide flush joints when attached to the PVC pipe.

Machine slotted PVC screens with No. 20 slot openings were used for the 102 mm and 51 mm PVC bedrock piezometers. Machine slotted screens with No. 10 slot openings were installed on the 19 mm overburden piezometers. All screens and slotted intervals were fitted with a blank piece of pipe which acts as a sediment sump. The sump is 1 m long on the 102 mm diameter and varies in length between 0.08 and 0.3 m for the 19 mm diameter monitor. The annulus around the screens was backfilled with silica sand to about 0.3 m above the top of the screen. The bottom of each monitor was finished with a friction-fit PVC cap to prevent materials from entering the monitors.

Seals

A bentonite seal was installed directly above the sand pack. The seals are about 3 m or more in thickness in the deeper piezometers and consist of bentonite pellets ("pelltonite"), bentonite gravel ("hole plug") and bentonite powder ("quick gel"). The bentonite seals in the bedrock monitors are installed to a minimum thickness of 3 m, above the bedrock surface and are extended to above the top of the lower till. Bentonite seals installed in dry overburden boreholes were wetted with clean water to swell the bentonite and thus prevent grout from entering the silica sand pack and monitor screen. The thickness of bentonite seals in the shallowest overburden monitors will vary depending upon the depth from surface of the top of the screens.

Backfill

The annular space above the bentonite seal was backfilled to within about 0.5 m of the ground surface with a bentonite-cement grout mixture. In water-filled boreholes, the grout was installed through a tremie line from the top of the bentonite seals to within about 0.5 m of surface to displace the water in the borehole. The composition of the grout, which is similar to that used in the Phase 4A drilling program, is summarized on a per cent weight basis.

Grout Slurry Composition (% Weight)

1.5 - 3.0%	- Bentonite (Quick Gel)
40 - 60%	- Cement (Portland Type 10)
40 - 60%	- Water

Quantities of materials used in each batch of grout slurry were recorded on a Borehole Plugging Plan/Record (Figure A2-6). Chlorinated potable water from the Vineland municipal water supply system (part of St. Catharines municipal system) was used in the grout mixtures. Samples of each batch of grout were taken and retained to verify proper setting of the grout.

Surface Casing

A protective steel casing with a locking cap was installed over each monitor after the grout backfill hardened. The casing is adjusted to the proper height with silica sand placed on top of the grout backfill. The casing was then cemented in place with cement-bentonite grout. The drilling location and borehole number were stamped onto each protective casing for ease of identification. Protective casings for the 102 mm, 51 mm and 19 mm diameter monitors have respective diameters of 305 mm, 203 mm

FIGURE A2-6

A-34



Gartner
Lee
Associates
Limited

BOREHOLE PLUGGING PLAN / RECORD

PROJECT: _____

SITE: _____

CLIENT: _____

BOREHOLE: _____ BY: _____

LOCATION: _____ CONTRACTOR: _____

DATE: _____ DRILLER: _____

VOLUME CALCULATION:

- | | | | |
|--|---|-------|---|
| 1. Hole Depth (m) | = | _____ | |
| 2. Bit Diameter (mm) | = | _____ | |
| 3. #2 x 1.1 (mm) | = | _____ | = Estimated Hole Diameter |
| 4. #3 ÷ 2 ÷ 1000 (m) | = | _____ | = Estimated Hole Radius in Meters |
| 5. (#4) ² x Pi(m ²) | = | _____ | = Hole Volume/meter (m ³ /m) |
| 6. #1 (m) x #5 (m ³ /m) | = | _____ | = Hole volume (m ³) |
| 7. Additional % | = | _____ | = Volume for mixing (m ³) |
| 8. Total volume | = | _____ | = Volume for mixing (L) = _____ (L) |

MIXING QUANTITIES/STAGE:

	TOTAL	STAGE 1	STAGE 2	STAGE 3
9. #8 Volume Grout (L)	_____	_____	_____	_____
10. Required Cement (bags)	_____	_____	_____	_____
11. Required Water (L)	_____	_____	_____	_____
12. Required Bentonite (L)	_____	_____	_____	_____

PUMPING QUANTITIES/DEPTHS:

13. Time Initial Circulation Achieved	_____	_____	_____	_____
14. Start Mixing Time	_____	_____	_____	_____
15. End Mixing Time	_____	_____	_____	_____
16. Start Pumping Time	_____	_____	_____	_____
17. End Pumping Time	_____	_____	_____	_____
18. Volume Grout Pumped	_____	_____	_____	_____
19. Depth of Rods	_____	_____	_____	_____
20. Return Achieved (Yes/No)	_____	_____	_____	_____

21. DESCRIPTION OF UPPER METER: _____

22. COMMENTS: _____

23. WEATHER

and 102 mm. The casings are 1.5 m in length and extend 0.5 to 0.75 m below ground surface leaving 0.75 to 1.0 m of the casing above ground.

A2.3.2 STANDPIPES

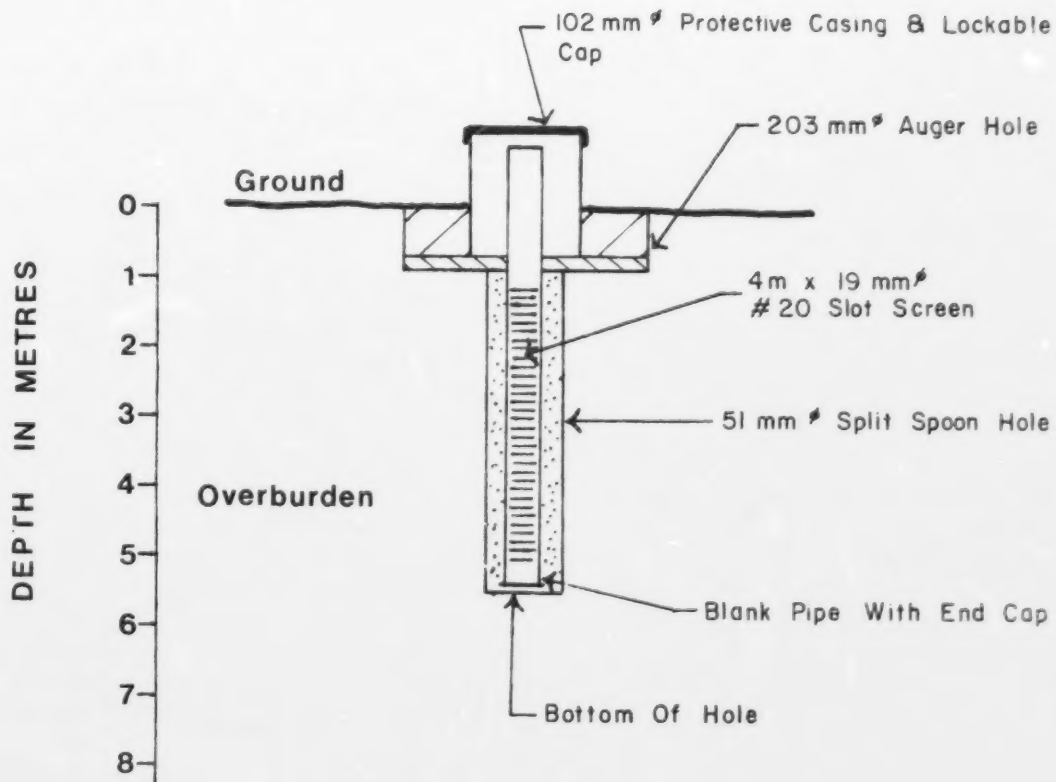
A shallow ground water monitor (standpipe) was installed at each of the 12 on-site drilling locations and four off-site drilling locations. Each standpipe was installed to a depth of between 5.5 m and 5.8 m and consists of 19 mm diameter PVC pipe. Figure A2-7 shows the construction details of a typical standpipe.

The 3 m to 4 m lower portion of the standpipes are machine slotted with No. 20 slot opening. The bottom of the standpipe has a blank segment of pipe which acts as a sediment sump and is between 0.08 to 0.3 m in length. A PVC cap was friction-fitted to the bottom of each standpipe to prevent materials from entering the pipe.

The slotted interval of the standpipe was backfilled with a silica sand pack. This material fills the annular space around the slotted interval to a maximum of about 0.8 m above the slots. A bentonite seal consisting of bentonite gravel was placed above the silica sand to a thickness of 0.1 m to 0.4 m. Under dry borehole conditions the bentonite was generally wetted with a small quantity of water to promote swelling of the bentonite prior to backfilling with grout. This inhibits the downward movement of grout into the sandpack. The annular space around the standpipe was backfilled with a cement-bentonite grout mixture to within 0.3 m to 0.5 m of the ground surface.

Figure A2-7

Standpipe Construction Details



LEGEND

-  CEMENT-BENTONITE GROUT
-  BENTONITE SEAL
-  SILICA SANDPACK

A protective surface casing was installed over the stand-pipe in the same manner as those for the piezometers. A description of the casing installation is provided in the previous section.

A2.3.3 PNEUMATIC PIEZOMETERS

A total of 14 pneumatic piezometers were installed on-site. This includes two pneumatic piezometers within the overburden at each of five locations and two pneumatic piezometers in bedrock at each of two locations. Construction details of the pneumatic piezometer installations are shown in Figure A2-8 and summarized in the following discussion.

Pneumatic piezometers are designed to measure pore water pressure within soil or rock by means of a pressure activated diaphragm. The diaphragm is mounted inside a pore pressure transducer which is installed to a predetermined depth within the borehole and sealed in place. The transducer is connected to the surface with two polyethylene tubes encased in a water-proof polyethylene jacket. Downhole pore pressures are obtained by pressurizing the diaphragm through one of the polyethylene connecting tubes and measuring the pressure by means of a pressure meter.

Transducers were supplied by Sinco Slope Indicator Company; detailed specifications (model #514178) are shown in Figure A2-9.

The transducers were wrapped in a silica sand-filled filter cloth "sock". The sock was saturated with water prior to installation to dissipate air bubbles from around the transducer. This prevents air locking around the diaphragm and also reduces the

Pneumatic Piezometer Construction Details Figure A2-8

PNEUMATIC PIEZOMETERS AND STANDARD PIEZOMETER IN BEDROCK

PNEUMATIC PIEZOMETERS IN OVERBURDEN

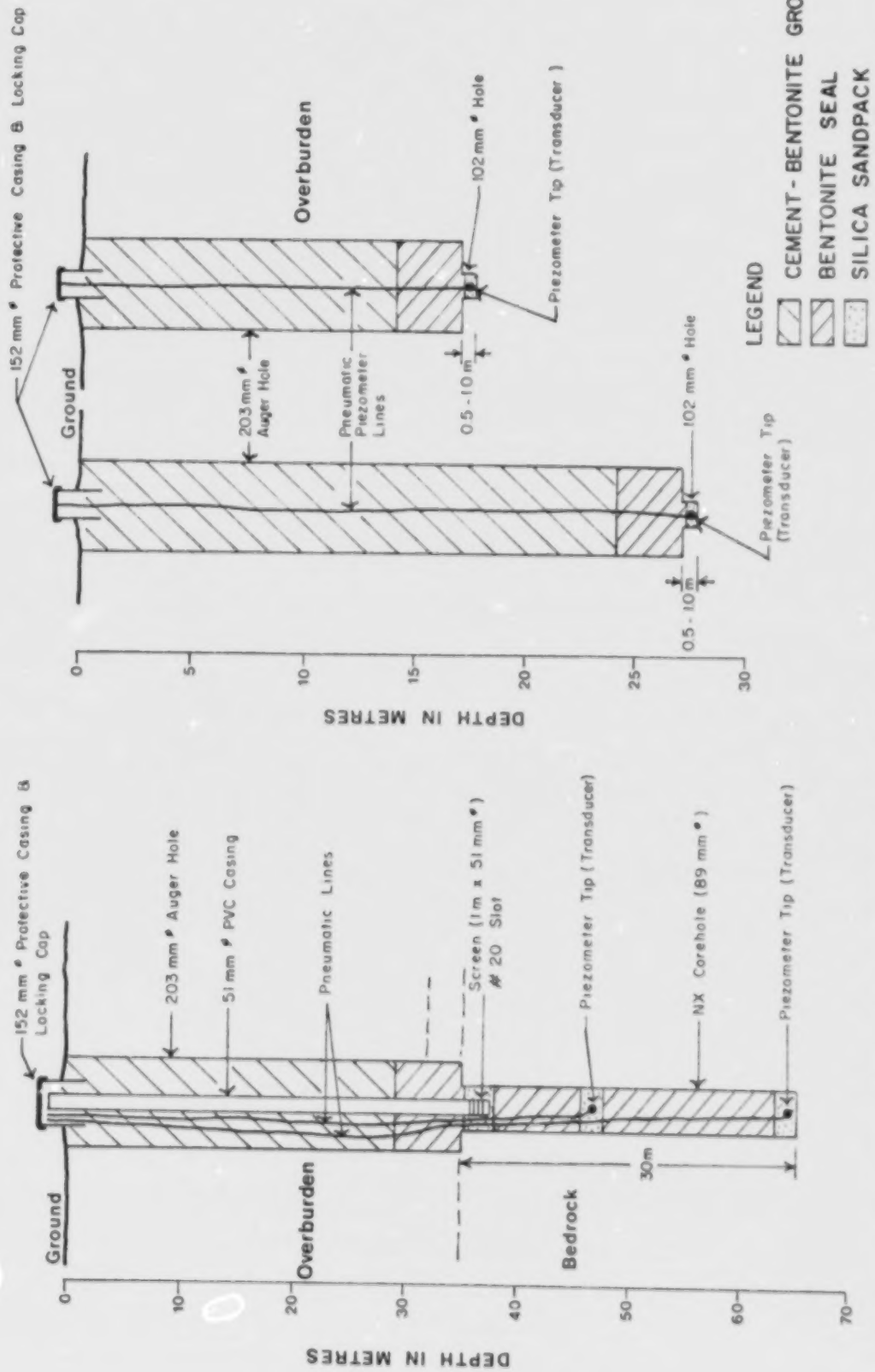


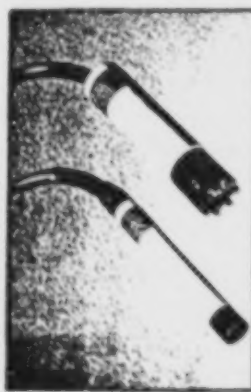
Figure A2-9

PORE-PRESSURE TRANSDUCER 514177 & 514178

The Models 514177 and 514178 are low cost, rugged, portable pressure transducers for determining pore water or gas pressure within embankments, foundations, and slide areas. The systems feature high sensitivity, superior repeatability, and low diaphragm displacement. Two sizes of transducer are available. Model 514177 has a 5/8" O.D. and Model 514178 has a 1" O.D.

The transducer converts fluid pressure into pneumatic pressure which can be relayed to a remote reading station. The basic principle of operation is a hydro-pneumatic balance of forces across a flexible diaphragm.

A variety of terminal stations and portable or wall-mounted indicators provides flexibility to meet various requirements. These are coupled to the pore pressure transducer by means of polyethylene or nylon tubing in a water proof polyethylene jacket. This tubing is designed for direct burial and will withstand rough handling in the field. The two transducer models can both be operated with either a 2 tube or a 3 tube configuration. Accuracy is increased with longer tube lengths with a 3 tube system.



Model 514177 Model 514178

DESCRIPTION AND SPECIFICATIONS

Pore water pressure acts upon a flexible diaphragm having negligible spring force. The force of the diaphragm due to water pressure causes a valve to close. To take a reading, when using the 3 tube arrangement, gas pressure is applied through the input tube allowing flow into the chamber and into the output tube which is connected to a high precision pressure gauge in the reading station. Pressure in the chamber and two tubes increases until a balance is achieved between pore water pressure & gas pressure. A pressure gauge in the chamber & two tubes indicates valve and thus pore pressure. The measurement may be repeated by reducing input pressure to a level below the output pressure gauge reading at which point it will begin to decrease. The output pressure is increased again and the reading is repeated.

The Pore-Pressure Transducer Model 514177 has a 5/8" O.D. and Model 514178 has a 1" O.D. The high precision pressure gauge in the chamber measures the pore pressure to the transducer. The difference between the pore pressure and the input pressure increases with longer tube lengths and higher flow rates of pressure. However, as long as repeatable reading pressures are maintained and pore pressure changes are not extreme, high precision can be achieved.

For many applications, the flow rate may be limited by the valve operation to avoid reading error. For the extreme, an accurate and sensitive rapid pressure gauges, the flow condition is maintained with a "locking" ball. Transducer. By maintaining control flow for each reading, the pressure due to flow rate and pressure operator error is eliminated. Taping lengths for the 3 tube system may be adjusted to suit conditions with no effect to the configuration of the Transducer.

Another major, of operation, which adds to its excellent results, is the over pressure method. Results are obtained by forcing a venting gas into the input tube until gas escapes through the vent tube. When gas is detected flowing from the vent tube, the input gas is interrupted and the vacuum port is slowly closed until the output value is closed. The vacuum pressure can then be measured in either the input tube or the output tube. The "over pressure" method is commonly used with "backflow" prevention means for means of measuring pore pressure.

This transducer does not require a pump or a battery and has negligible zero shift or changes in gauge factor. It provides a non-ambiguous measurement which is a result of the unique pneumatic hydraulic balance condition. The principle of the technique for measurement of pore water pressure results in an economical, stable and sensitive transducer. It is a long term repeatability for periodic measurement of fluctuating pressures. Normally, it is not necessary to refer to calibration curves at any time since the gauge factor is essentially 1.

A stainless steel disc liner is standard. Three additional types of porous liners are available. The Rapid Drainage, Turb and the priority-type liner have large pore size and are used for pressure. The Coarse liner has high air flow and is used for the measurement of water pressure whenever pore water pressure is also present.

Fluid pressure measurements may be continuously monitored and recorded on a chart or digital data logging equipment. Output signals may be compared to present through station or channel to trigger external alarms.

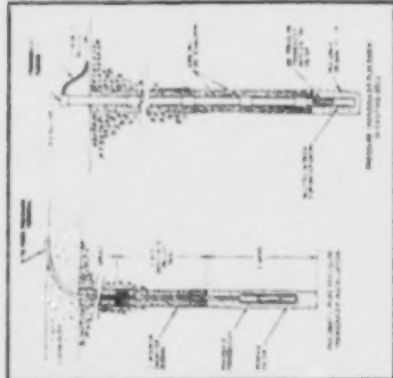
APPLICATION AND INSTALLATION

The transducer will operate in any position. It can be installed in a variety of ways. The transducer is mounted in a hole in the soil. The hole can be drilled into the soil and the transducer can be pushed into the soil and secured with a cap. The hole can be drilled into the soil and the transducer can be pushed into the soil and secured with a cap. The hole can be drilled into the soil and the transducer can be pushed into the soil and secured with a cap.

Reading Manifold can be placed in small bore fluid type well points in most cases. The 1" O.D. transducer with a Nylon tube adapter can be placed in larger bore fluid type well points. The adapter tube is made of stainless steel and is available in 1/2" and 1" diameters. The adapter tube is made of stainless steel and is available in 1/2" and 1" diameters. The adapter tube is made of stainless steel and is available in 1/2" and 1" diameters.

- Monitoring water pressure changes in regard to stability of slopes.
- Control of construction of embankments and dams.
- Spot data in situ to determine message patterns in soil and rock.
- Sampling of pore pressure in foundations.
- Sampling of pore pressure in embankments and foundations.
- Sampling of pore pressure in foundations and embankments.
- Monitoring of pore pressure subjected to static and dynamic loads.
- Monitoring of pore pressure subjected to static and dynamic loads.
- Monitoring of pore pressure subjected to static and dynamic loads.

Since this is a scientific instrument, measurements should be taken regularly and interpreted by qualified personnel. SINCQ is not responsible for errors or omissions of such personnel.



TRANSDUCER SPECIFICATIONS

Pressure Range	0-5,000 psig (344,600 kPa)
Repeatability	± 0.5%
Accuracy	± 0.5%
Cable Zero Offset	30 psi ± 0.5 psi ± 2% (2.1 kPa ± 35 kPa)
Sensitivity	1.007 ± 0.005
Diaphragm Displacement	0.01 in
Diaphragm Material	Bronze or Steel
Standard	When Rapid Drainage Liner
Optional	When Rapid Drainage Liner
Body	Model 514177
Model 514178	
Flange	Standard
Optional	Optional

5/8" Disc - 50 micron pore size (100 mesh) stainless steel
 Nylon Tube - 50 micron pore size, 1/2" (12.7 mm) O.D. x 4' (1.22 m) length
 25' (7.62 m) max. length
 Polyethylene - 50 micron pore size, 1/2" (12.7 mm) O.D. x 4' (1.22 m) length
 25' (7.62 m) max. length
 Coarse Liner - 15 to 20 micron pore size, 1/2" (12.7 mm) O.D. x 4' (1.22 m) length
 15' (4.57 m) max. length
 1/2" (12.7 mm) O.D. x 4' (1.22 m) length, 25' (7.62 m) max. length



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time interval required prior to taking representative pore pressure readings.

In the case of bedrock installations, two pneumatic piezometers were installed at different depths within the same borehole. Bentonite gravel was used to backfill the borehole to the appropriate depth for the transducer installation. The transducer, wrapped in the filter cloth sock, was then installed and silica sand placed in the annular space around the transducer to 0.3 m to 0.8 m above the top of the transducer. The borehole was then backfilled with bentonite gravel to the level at which the upper transducer was to be placed. The installation and backfilling of the second transducer was completed in a similar fashion. Bentonite gravel was used to backfill and seal the borehole above the upper transducer to about 3 m below the bedrock surface. A standard piezometer was installed within the upper 3 m of bedrock in the same borehole.

Overburden pneumatic piezometers were installed using similar installation procedures. Only one transducer was installed in each borehole. Overburden boreholes were generally dry during installation of the pneumatic transducers. At drilling location 85-3 (Figure A2-1) a small amount of water was added to the borehole prior to installing the transducer. The silica sand pack and the transducer were installed under saturated conditions at the bottom of this borehole. The filter cloth sock and transducer were also saturated prior to installation. Pre-saturation of the borehole was only completed at location 85-3 and not at the eight other overburden pneumatic piezometer installations for comparison purposes. A bentonite gravel seal of 3 to 4 m in thickness was placed over the silica sand backfill placed around the pneumatic piezometer. The bentonite seal was

wetted with clean water after installation. Bentonite-cement grout was used to backfill the boreholes from the bentonite seal to within 0.5 to 1.0 m of the ground surface. Protective steel casings were installed at surface in a similar manner to the other piezometers.

A2.4 GEOCHEMISTRY MONITORS

A total of 38 water quality monitors were completed at five on-site drilling locations (locations 85-1, 85-3, 85-8, 85-10 and 85-12 in Figure A2-1). The water quality monitors are used for sampling of in situ ground water in both the overburden and bedrock. These monitors are constructed of 51 mm diameter PVC "Triloc" pipe and screens. The pipe which is in 3 m lengths, has specially threaded ends with rubber "O" ring seals which provide flush, water-tight joints. The screens are machine slotted with No. 20 slot openings for bedrock installations and No. 10 slot openings for overburden installations. The bottom of the screens are fitted with a blank tapered end. Three types of water quality monitors were installed.

- standard piezometers;
- standpipes; and
- shallow overburden profile monitors.

A2.4.1 STANDARD PIEZOMETERS

Bedrock monitors

Bedrock water quality monitors were installed at five on-site drilling locations. These monitors are completed within the upper 3 m of the bedrock and are similar in design to the standard hydrogeologic bedrock piezometer. The construction details are shown in Figure A2-10.

Water Quality Bedrock Piezometer, Construction Details

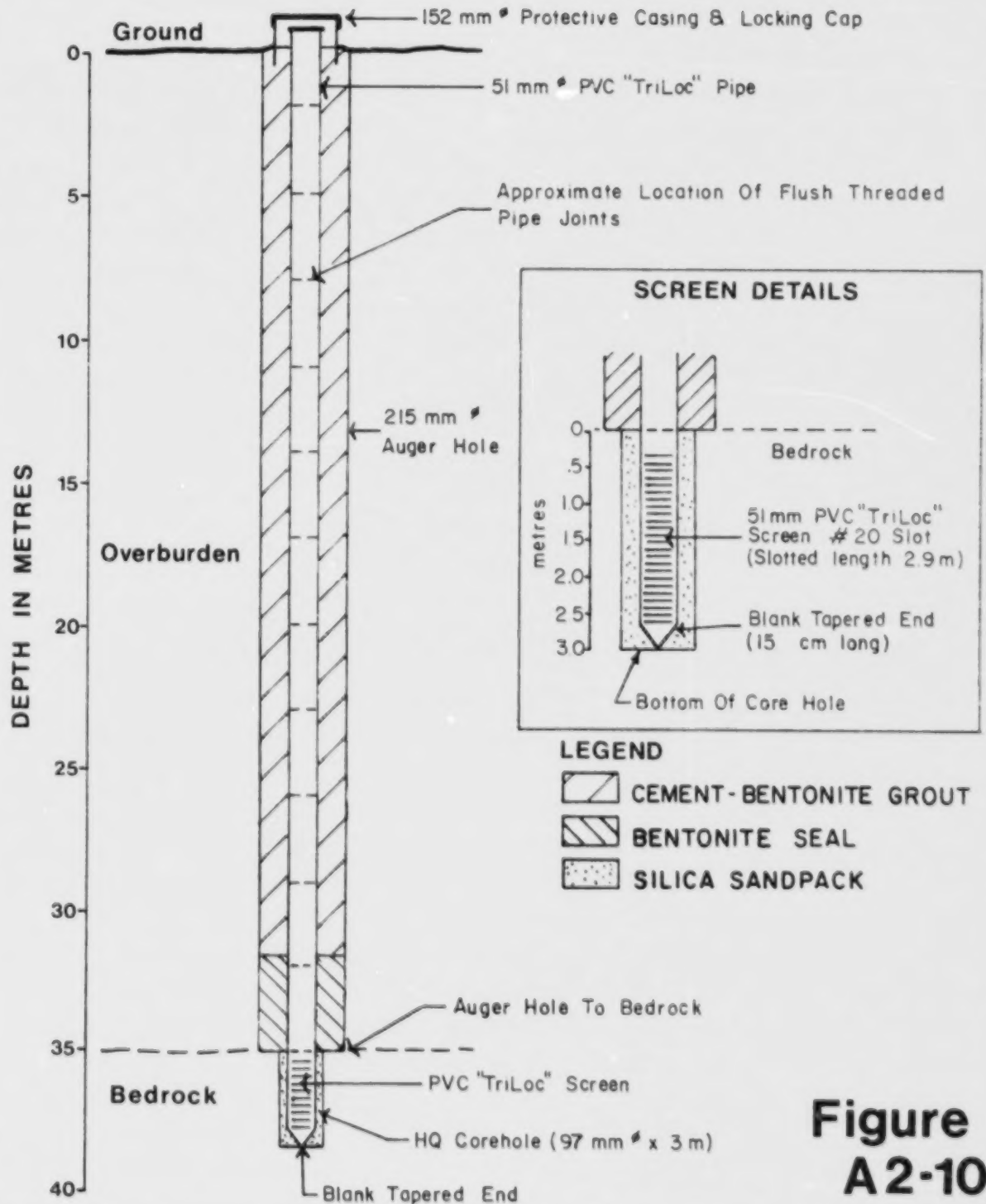


**Figure
A2-10**

The design of the bentonite seals was modified at some locations due to problems with materials clogging the inside of the borehole. This was the case in monitor 85-10-1 where a 10 m thickness of bentonite slurry was installed above 1.7 m of peltonite for a total seal thickness of 11.7 m above the silica sand pack. A thicker seal was also installed at monitor 85-12-1 to provide a secure seal above the highly fractured bedrock. The seal at 85-12-1 consists of 6 m of bentonite gravel above 2 m of bentonite pellets for a total seal thickness of about 8 m. Significant quantities of silica sand were required at 85-12-1 because the bedrock was extensively fractured. Consequently the upper 1 m of bedrock could not be backfilled with silica sand and was backfilled with caved material as the augers were pulled up.

Overburden monitors

Two water quality monitors were installed in the overburden at the five on-site locations. These monitors were installed under dry borehole conditions. They are constructed of 51 mm diameter PVC "Triloc" pipe and screens. Construction details are shown in Figure A2-11.

The screens consist of 0.6 m lengths of 51 mm diameter PVC "Triloc" machine slotted pipe with No. 20 slot openings. The screens were wrapped in a filter cloth (geotextile) sock which was fastened to the screens by three plastic clips. Silica sand was not used around the screens, instead the top of the split spoon hole in which the screens were inserted was covered with a PVC ring and rubber plug as shown in the screen details in Figure A2-11. The annular space between the screen and the sides of the split spoon hole was left empty to minimize the potential for air locking within the sand pack, which could

Water Quality Overburden Piezometer Construction Details

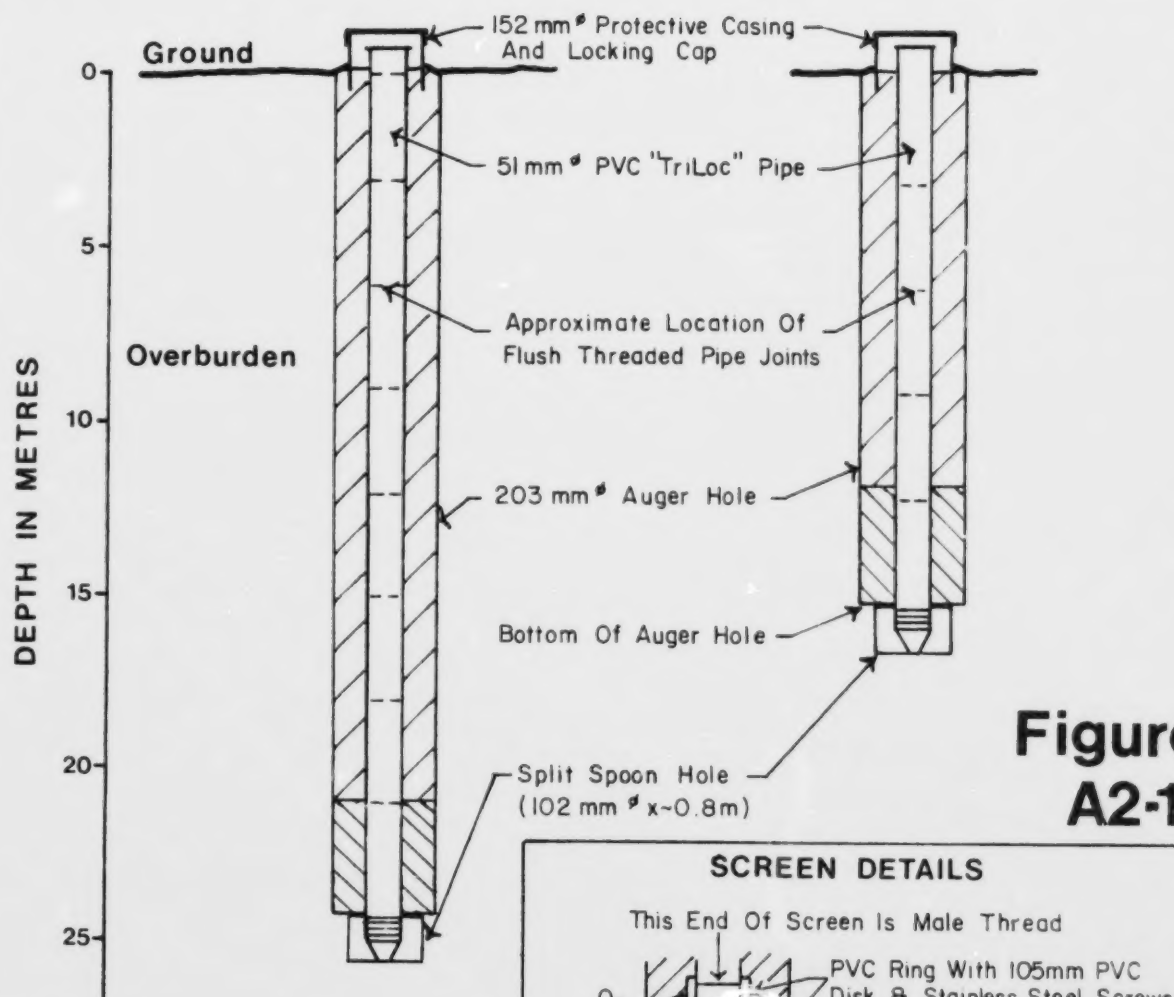
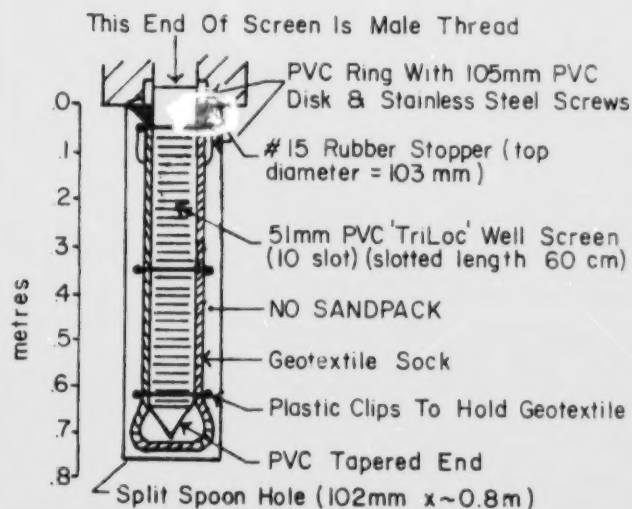


**Figure
A2-11**

LEGEND

- CEMENT-BENTONITE GROUT
- BENTONITE SEAL

SCREEN DETAILS



alter the ground water chemistry. The depth of installation of the screens in the two overburden water quality monitors is about 15 m and 25 m respectively, from the ground surface.

The bentonite seal installed in these monitors is layered, consisting of bentonite pellets, bentonite gravel and bentonite powder. The seal was installed above the PVC ring and rubber stopper as shown in Figure A2-11. The minimum thickness of the bentonite seals is 3.3 m. The bentonite seals were wetted with clean water prior to backfilling the hole with grout. As with all other monitors, a cement-bentonite grout mixture was used to backfill the borehole annular space above the bentonite seal to within 0.5 to 1.0 m of ground surface. The grout mixture was installed through a tremie line from the top of the bentonite seal.

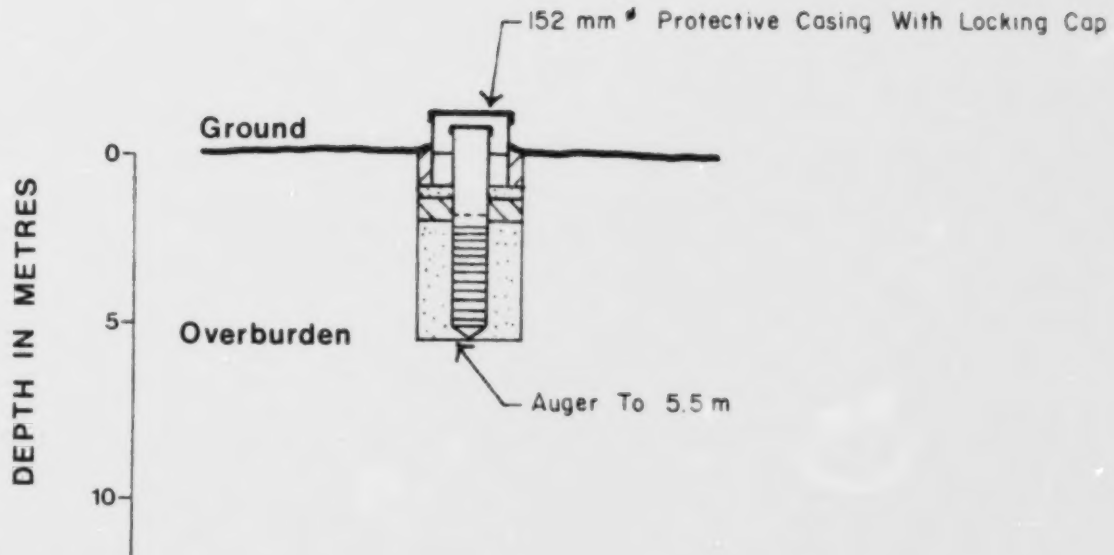
The overburden water quality monitors are protected at surface with a 152 mm diameter protective steel casing with locking cap. These casings were grouted in place after being adjusted to a convenient height. The protective casing installation was completed in a similar fashion to that described previously for the hydrogeologic monitors.

A2.4.2 STANDPIPES

Water quality standpipes are installed at five drilling locations (locations 85-1, 85-3, 85-8, 85-10 and 85-12 in Figure A2-1). The standpipes are constructed of 51 mm diameter "Tri-loc" PVC pipe and screens. They are completed to a depth of 5.5 m below ground surface. Construction details are shown in Figure A2-12.

Figure A2-12

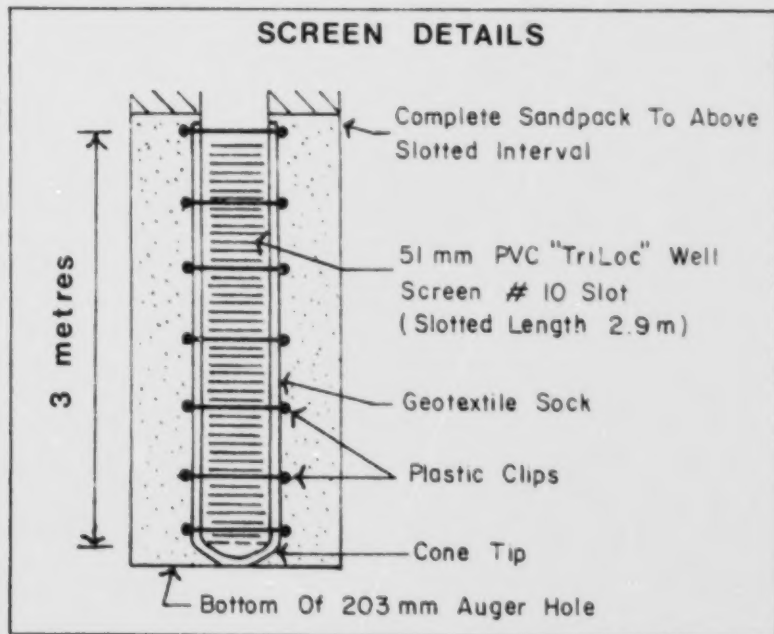
Water Quality Standpipe, Construction Details



LEGEND

-  CEMENT-BENTONITE GROUT
-  BENTONITE SEAL
-  SILICA SANDPACK

SCREEN DETAILS



The screens are machine slotted "Triloc" pipe with No. 10 slots over a 3 m segment. The bottom end of the screen was fitted with a tapered cone tip and the slotted interval was wrapped in a filter cloth sock which was fastened to the screen with several plastic clips. Silica sand pack backfilled around the screen to just above the top of the slotted interval.

Bentonite powder was added to the top of the silica sand pack as a seal to prevent surface water from entering the screen. The seal has a minimum thickness of 0.4 m. No water was added to the bentonite powder. Silica sand was placed above the bentonite to level and support the protective surface casing as it was being grouted in place.

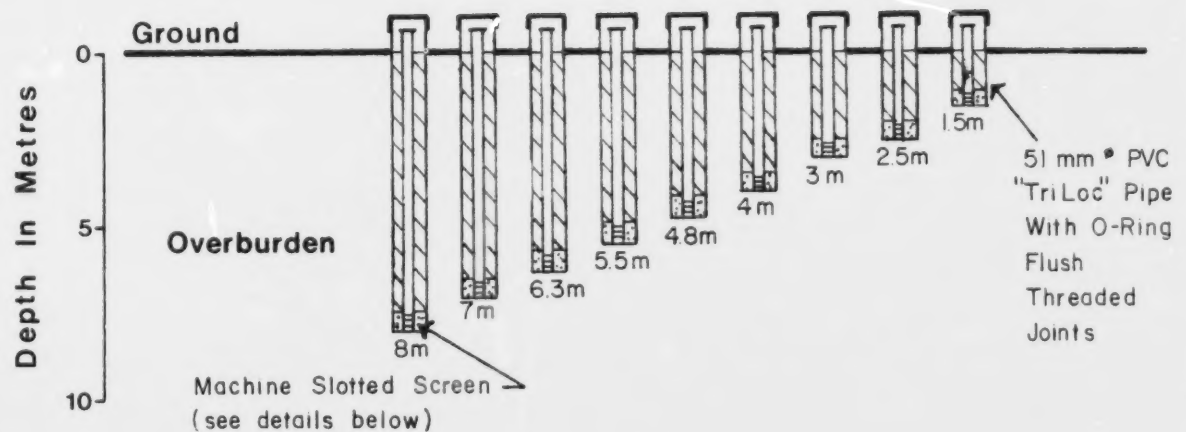
A cement-bentonite grout mixture was placed above the bentonite seal to fill the annular space around the monitor to within about 1 m of the ground surface.

A2.4.3 SHALLOW OVERBURDEN PROFILE MONITORS

A set of nine shallow water quality monitors were installed at each of the two detailed drilling locations, 85-1 and 85-12 (Figure A2-1). These monitors are constructed of 51 mm diameter PVC "Triloc" pipe with machine slotted screens. The purpose of these monitors is to allow for the sampling of ground water at various shallow depths between 1.5 and 8.0 m. Construction details for these monitors are shown in Figure A2-13.

The screens consist of 51 mm diameter PVC "Triloc" pipe with No. 10 sized machine slotted perforations extending over a 0.3 m length. The bottom of the monitor was capped with a friction-fitted PVC cap. The slotted interval was covered with a filter cloth (geotextile) sock held in place with two plastic clips.

Shallow Overburden Profile Monitors, Construction Details



LEGEND

-  Bentonite Seal
-  Silica Sandpack

SCREEN DETAILS

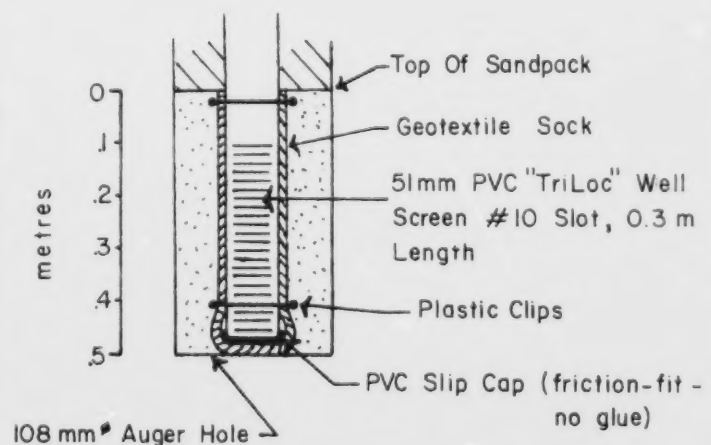


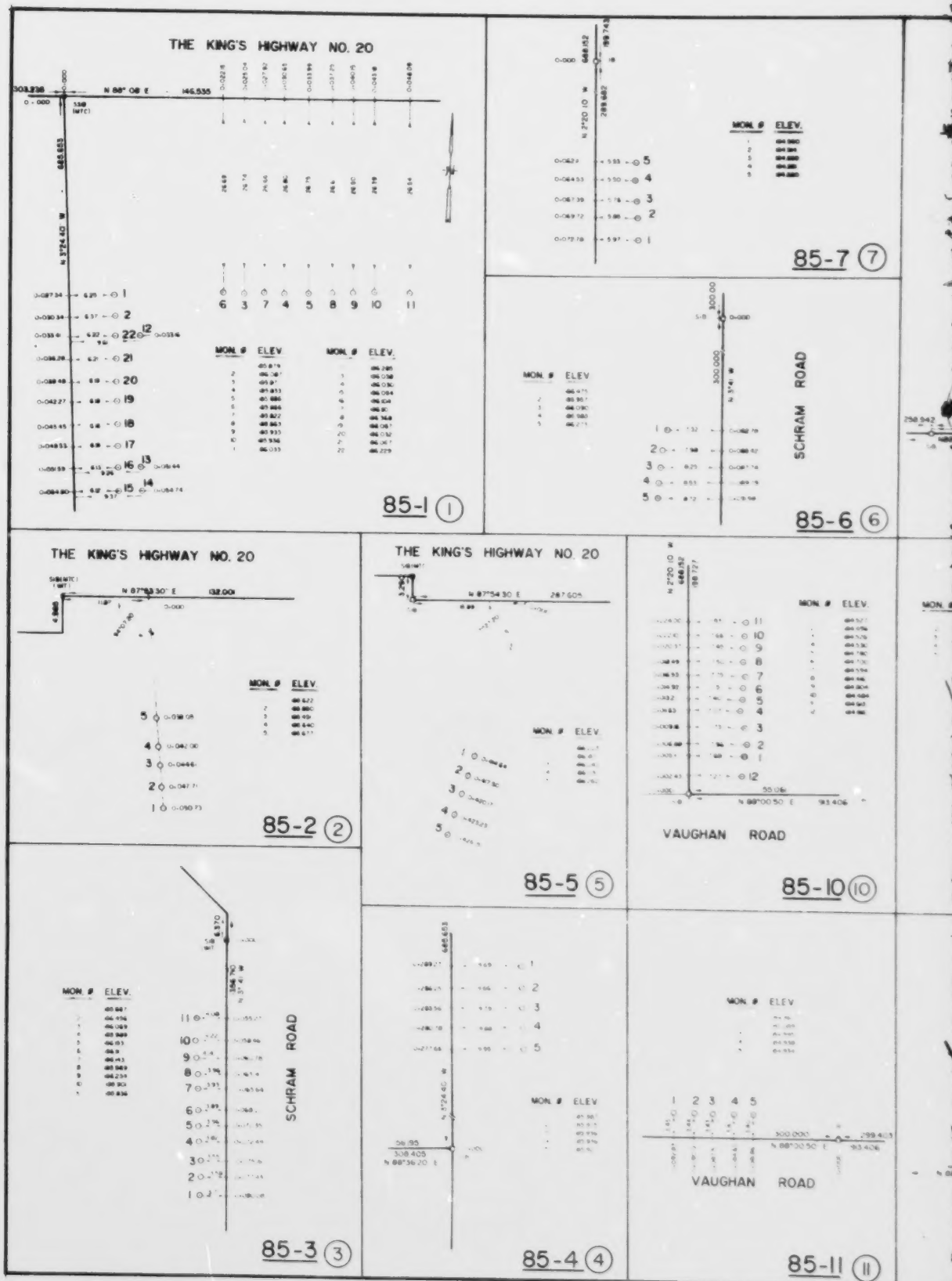
**Figure
A2-13**

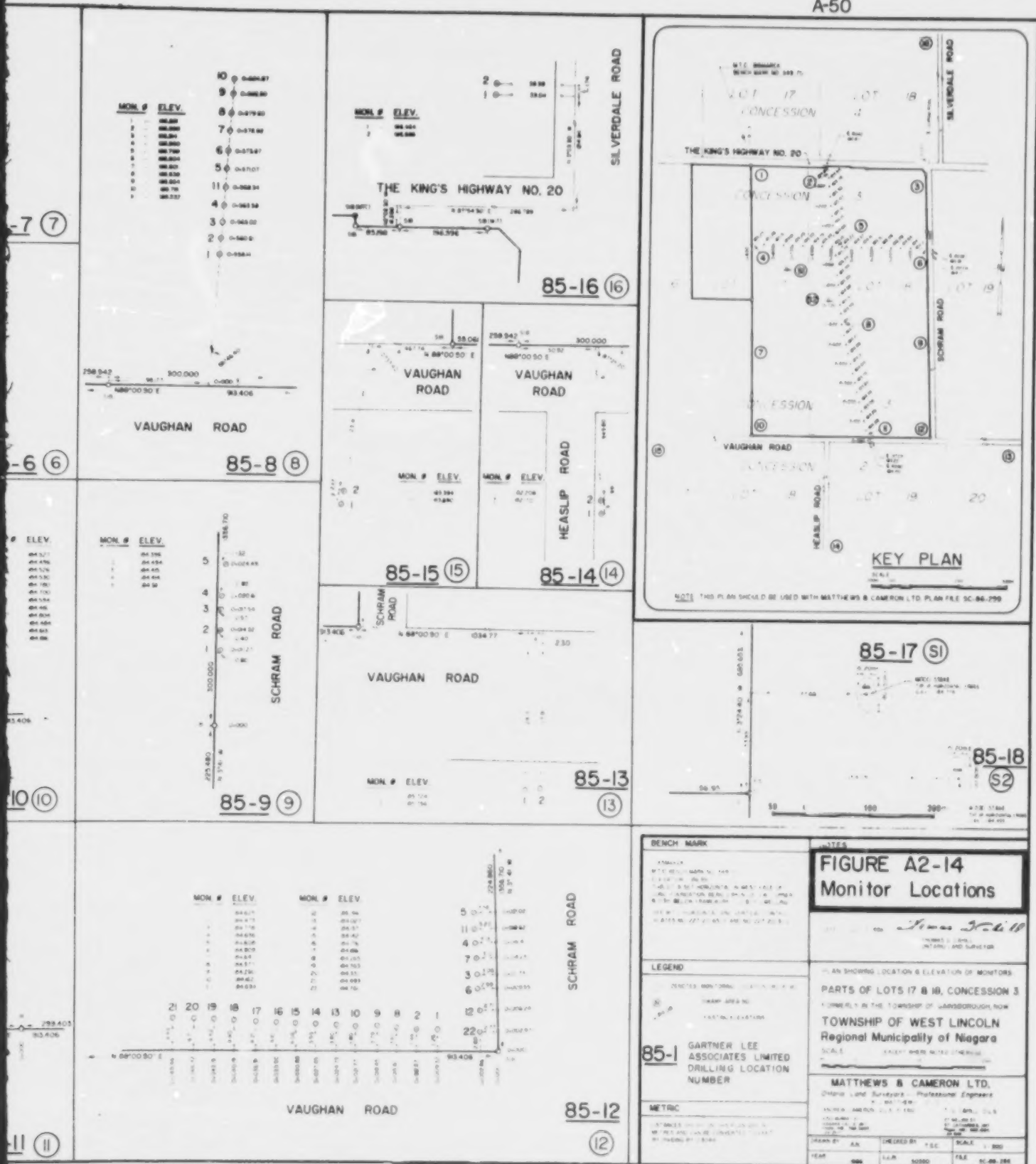
The annular space around the slotted interval was backfilled with silica sand to just above the top of the slotted interval.

The bentonite seals extend from above the silica sand pack to within less than 1 m of ground surface. The seals consist of bentonite pellets, bentonite gravel and bentonite powder.

Protective steel surface casings measuring 152 mm in diameter and 1.5 m in length were installed over each monitor. Each casing was installed to a depth of 0.6 to 1.0 m and was fitted with a locking cap. A surface seal was achieved by pushing the casing into the 108 mm diameter auger hole.

A legal survey of all monitors described above was completed by Matthews and Cameron Limited and their location relative to surveyed benchmarks are shown on Figure A2-14.





A3 WATER LEVEL MEASUREMENT AND HYDROGEOLOGIC TESTING

Protocols for conducting water level measurements and field and laboratory testing to establish hydrogeologic parameters are described in this Appendix.

This Appendix is organized as follows:

- water level measurement (Appendix A3.1);
- slug testing (Appendix A3.2);
- packer testing (Appendix A3.3);
- pump testing (Appendix A3.4); and
- laboratory testing (Appendix A3.5).

A3.1 WATER LEVEL MEASUREMENT

A3.1.1 PIEZOMETERS AND STANDPIPES

Water levels in all piezometers and standpipes, other than pneumatic piezometers, were measured using a Solinst Compact Water Level Meter (Model No. 1W4). The procedure for taking water level measurements is described below:

- (1) Remove protective casing cap and monitor cap.
- (2) Switch water level meter to "on"; test the battery using battery test button (if a "beep" is heard then batteries are charged). Ensure that the probe and cable are clean.
- (3) Lower the probe into the monitor slowly until a "beep" is heard indicating water.

- (4) Read the depth, to the nearest centimetre (0.01 m), from the graduated cable at the highest point on the top of the monitor pipe.
- (5) Repeat the measurement for confirmation.
- (6) Remove the probe from the monitor.
- (7) Replace monitor cap and lock the protective casing cap in place.

Measurements in the geochemistry monitors were undertaken using a water level meter which was dedicated for use in these monitors. The water level measurements are presented in Appendix F2.

A3.1.2 PNEUMATIC PIEZOMETERS

The specifications and the procedure for use of the Sinca Model 514196 Pressure Indicator are described in Figure A3-1. This instrument is used to measure the ground water pressure at the pneumatic piezometers, described in Appendix A2.3.3. The pressure measurement is converted into an equivalent water level elevation using the following formula:

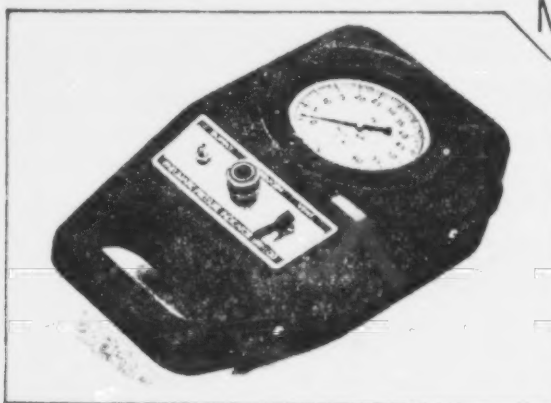
$$\begin{array}{rcl}
 \text{equivalent} & & \text{elevation of} & & \text{pneumatic} \\
 \text{water level} & = & \text{pneumatic} & + & \text{pressure} \times 0.704 \\
 \text{elevation (m)} & & \text{piezometer (m)} & & \text{reading} \\
 & & & & \text{(psi)}
 \end{array}$$

The 0.704 value is a constant which converts pressure in pounds per square inch (psi) to metres of hydraulic head. Equivalent water level elevations are presented in Appendix F2.

Figure A3-1

Pneumatic Pressure Indicator

Model 514196



The Model 514196 Pressure Indicator was designed to be economically priced and simple to operate. This unit incorporates the same high quality components as our other pneumatic pressure indicators into a custom-made, easy to handle ABS plastic case.

When combined with the Models 514177 and 514178 piezometers, the system is used for studies relating to hydrogeology, geotechnical and geophysical applications.

The indicator operates on a simple over-pressurizing technique for reading the transducer, which reduces operator error. The pressure gauge (0-60 psi with 1% accuracy) responds directly to the input supply, which can be a bicycle pump, automotive air supply, or portable pressure bottle.

To operate the system, simply connect the transducer to the quick connector, and the air supply to the tire valve. Input pressure should be continued until air escapes from the vent tube of the transducer. The operator then shuts down the supply and waits for the pressure on the gauge to stabilize. This method will result in accurate, repeatable readings. A vent valve on the indicator can be used to bleed the air from the gauge and transducer.

SPECIFICATIONS

Size: 13.5 x 7.25 x 5 in (343 x 184 x 127 mm)

Weight: 5 lb (2.3 kg)

Maximum Operating Pressure: 60 psi (700 kPa)

Accuracy: 0.50% Full Scale

Gas Source: Bicycle Pump, Automotive Air Supply or Portable Pressure Bottle

LIMITED WARRANTY: The Slope Indicator Company warrants all products sold by it to be free of defects of workmanship and materials for a period of one year from the date of delivery by it. The OBLIGATION OF THE SLOPE INDICATOR COMPANY is hereafter LIMITED to REPLACEMENT or, AT ITS OPTION, REPAIR of products returned to it WITH TRANSPORTATION CHARGES PREPAID and which its examination shall disclose, to its satisfaction, was were not free from such defects.

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A3.2 SLUG TESTING

A3.2.1 INTRODUCTION

Slug tests were performed on water level monitors to determine the in situ hydraulic conductivity of the hydrostratigraphic unit. This is accomplished by analysing the water level response in the monitor following instantaneous change in water level. A more complete discussion of the background, theory, and applications of slug testing is provided in Hvorslev (1951), Cedergren (1967), and Freeze and Cherry (1979). The slug test results are presented in Appendix G2.

A3.2.2 EQUIPMENT

The following equipment was used in conducting all slug tests with the exception of those performed on bedrock monitors:

- Solinst Compact Water Level Meter;
- stopwatch or other accurate timepiece; and
- "slugs" for displacing water in the monitors.

<u>Slug Type</u>	<u>Length</u>	<u>Diameter</u>
Aluminium	1.825 m	0.010 m
Nylon	1.530 m	0.010 m

All data were recorded on Slug Test Field Sheets (Figure A3-2).

The following equipment was used in conducting slug tests on bedrock monitors:

COMPLETED BY: _____ CHECKED BY: _____

[illegible]

NOTE: (1) Test may be stopped when $h = H - 0.37(H - H_0)$
 (2) BTOP = "Below Top Of Pipe"
 (3) h:m:s = hours:minutes:seconds

- Hewlett Packard HP 9816 computer with data acquisition software;
- Hewlett Packard 3456A Digital Voltmeter;
- Druck PTX160/D Pressure Transmitter, cable, and 12-volt battery;
- monitor seal apparatus with 3-way valve and pressure gauge;
- nitrogen gas cylinder and regulator
- electrical generator;
- Solinst Compact Water Level Meter; and
- nylon slug, 0.039 m diameter, 1.208 m length.

A3.2.3 METHOD

The procedure for conducting all slug tests with the exception of those performed on bedrock monitors is described below.

- (1) Record appropriate initial data on the field sheet (Figure A3-2).
- (2) Measure the static water level in the monitor and record on the field sheet (water level measurement is described in A3.1).
- (3) Insert or withdraw an appropriately sized slug and note the time or start the stopwatch (Note: if a slug withdrawal test is performed, the slug must be placed in the monitor in advance such that the monitor has fully recovered to static prior to the test).
- (4) Measure the water level in the monitor immediately on insertion or withdrawal of the slug and record as the initial level on the field sheet.

- (5) Continue to measure water levels at appropriate time intervals such that sufficient data are obtained and record both the time and the water level measurement. The test may be discontinued when $H_x/H_o \leq 0.37$ (level at which curve match point reached).

The procedure for conducting slug tests on bedrock monitors is described below.

- (1) Measure and record the static water level using a water level meter.
- (2) Set up equipment as shown schematically in Figure A3.3.
- (3) Start data acquisition program to monitor water pressure at the transmitter and record the static pressure.
- (4) Seal off the top of the borehole by tightening the monitor seal apparatus and closing the 3-way valve.
- (5) Pressure the borehole from atmospheric to 6 - 30 kPa using the nitrogen gas cylinder. Wait until the water level has stabilized (when the transmitter pressure is constant).
- (6) Open the 3-way valve to instantaneously release the pressure in the borehole (the computer will automatically record the rise in water level at 0.5s intervals via the transmitter).
- (7) Upon completion of the test unseal the monitor, leaving the pressure transmitter downhole.

Schematic Diagram Of Bedrock Slug Testing Equipment

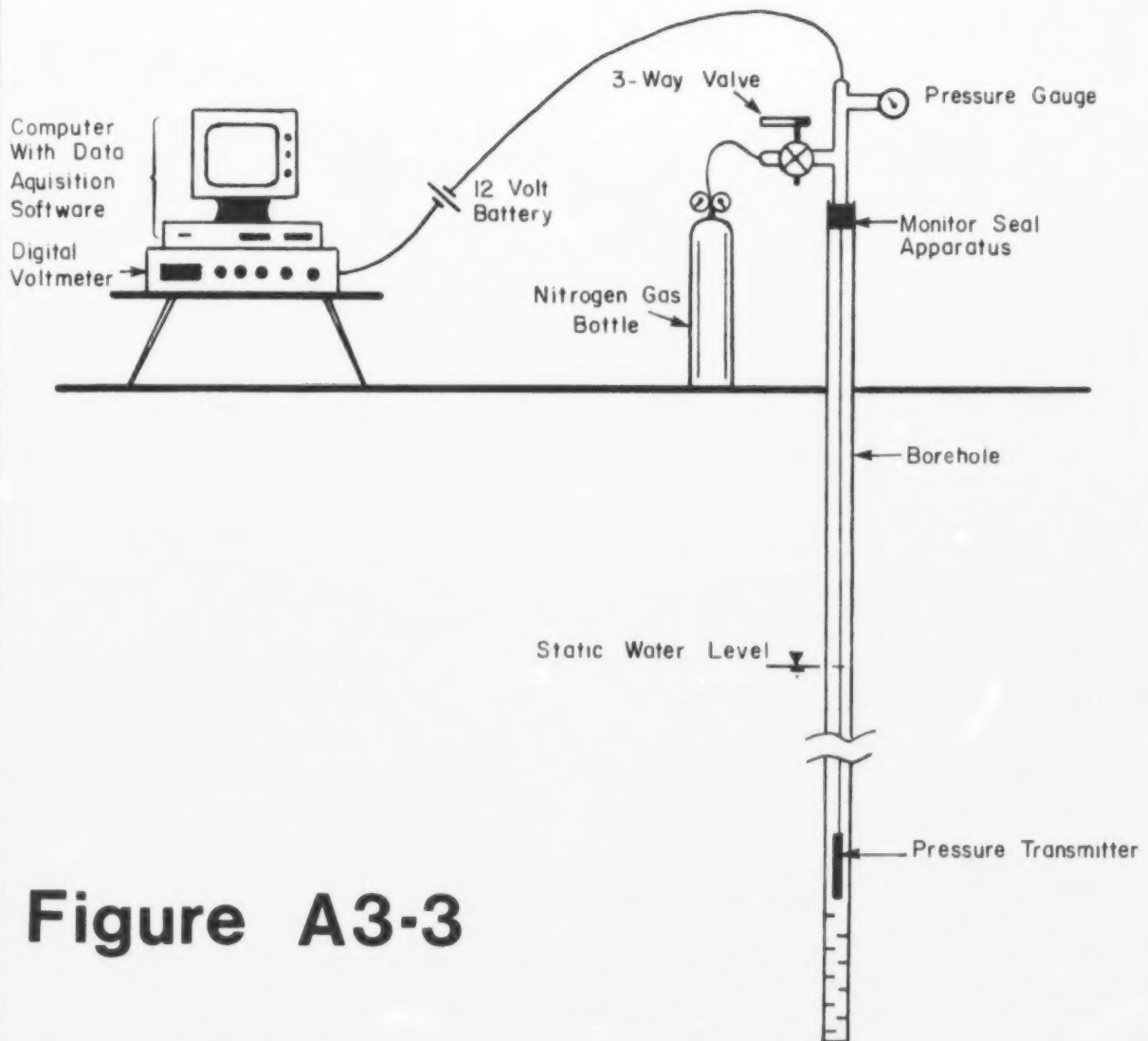


Figure A3-3

- (8) Conduct a slug injection test by rapidly dropping the nylon slug into the water until the slug is completely submerged (the computer will automatically record the rise and decline of the water level at 0.5s intervals via the transmitter).
- (9) Conduct a slug withdrawal test by rapidly removing the nylon slug out of the water (the computer will automatically record the decline and rise of the water level at 0.5s intervals).
- (10) Stop the data acquisition program and disassemble the testing equipment.

A3.3 PACKER TESTING

A3.3.1 INTRODUCTION

Packer testing was performed to assess the hydrogeologic characteristics of the bedrock at various depths. Analysis of the test data provides values of hydraulic conductivity, storage coefficient, and static water level.

Packer testing was performed at two on-site boreholes, 85-1-1 and 85-1-12. Eleven tests were performed in borehole 85-1-1 at 3 m intervals between the depths of 39 to 72.4 m. Nine tests were performed in borehole 85-1-12 at 3 m intervals between the depths of 36 to 63 m. Specific intervals judged to be more permeable based on initial packer testing were retested using the slug-test method. Intervals judged to be less permeable were retested using a constant-head method. The testing methods are described in Section A3.3.4. The packer testing results are presented in Appendix G3.

A3.3.2 EQUIPMENT

The packer testing equipment is illustrated schematically in Figure A3-4.

The downhole equipment consists of two Roctest inflatable rubber packers separated by a perforated steel pipe. The packers are capable of sealing boreholes ranging from 63 to 114 mm in diameter. The packer system was lowered into position using a 19 mm inside diameter galvanized steel standpipe by means of a tripod and winch. The packers were inflated through 4.8 mm diameter nylon tubing which extends to the surface.

A cylinder of compressed nitrogen was used to inflate the packer and to manipulate the water level to conduct the testing. The nitrogen was fed through an adjustable manifold so that the tasks could be carried out independently at different pressures.

The data acquisition system includes:

- Hewlett Packard HP860 strip chart recorder;
- data logger; and
- Druck PTX160/D pressure sensor.

Power was supplied to the data logger and strip chart recorder by a portable generator. The generator also powered the variable direct current supply required for the pressure sensor.

A3.3.3 METHOD

A discussion of the packer testing equipment and procedure is provided in the reports prepared by Waterra Hydrogeology Inc. (Appendix G3).

Schematic Diagram Of Bedrock Packer Testing Equipment

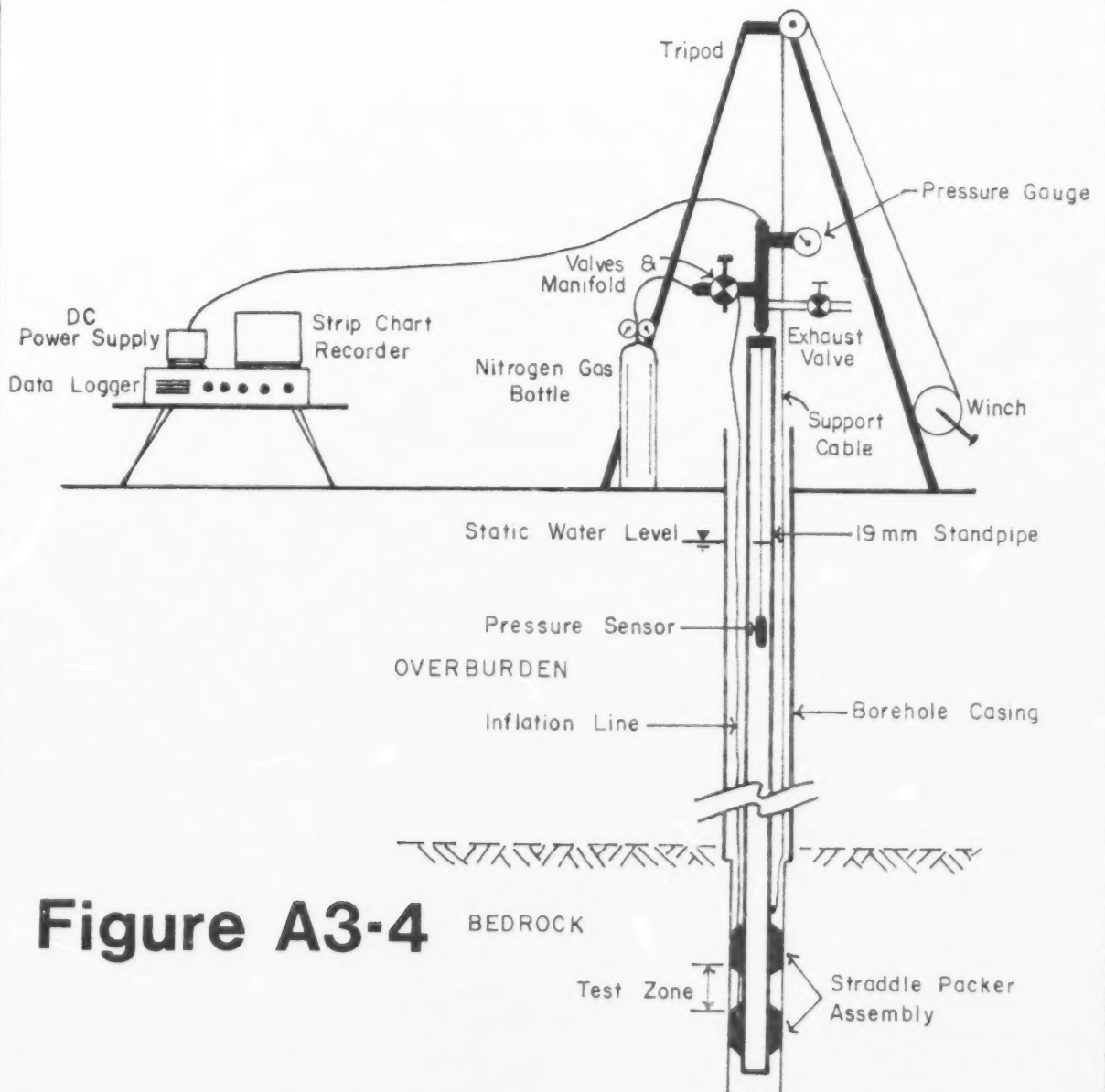


Figure A3-4

A3.4 PUMP TESTING

A3.4.1 INTRODUCTION

A pump test was conducted on borehole 85-1-22 to provide hydrogeologic data on the upper 3 m of the bedrock aquifer. Ground water levels in the bedrock were monitored in a number of adjacent observation wells at the time of testing. In addition, ground water levels within the overlying Lower Till Unit were also monitored to determine the extent of hydraulic connection between the till and the bedrock.

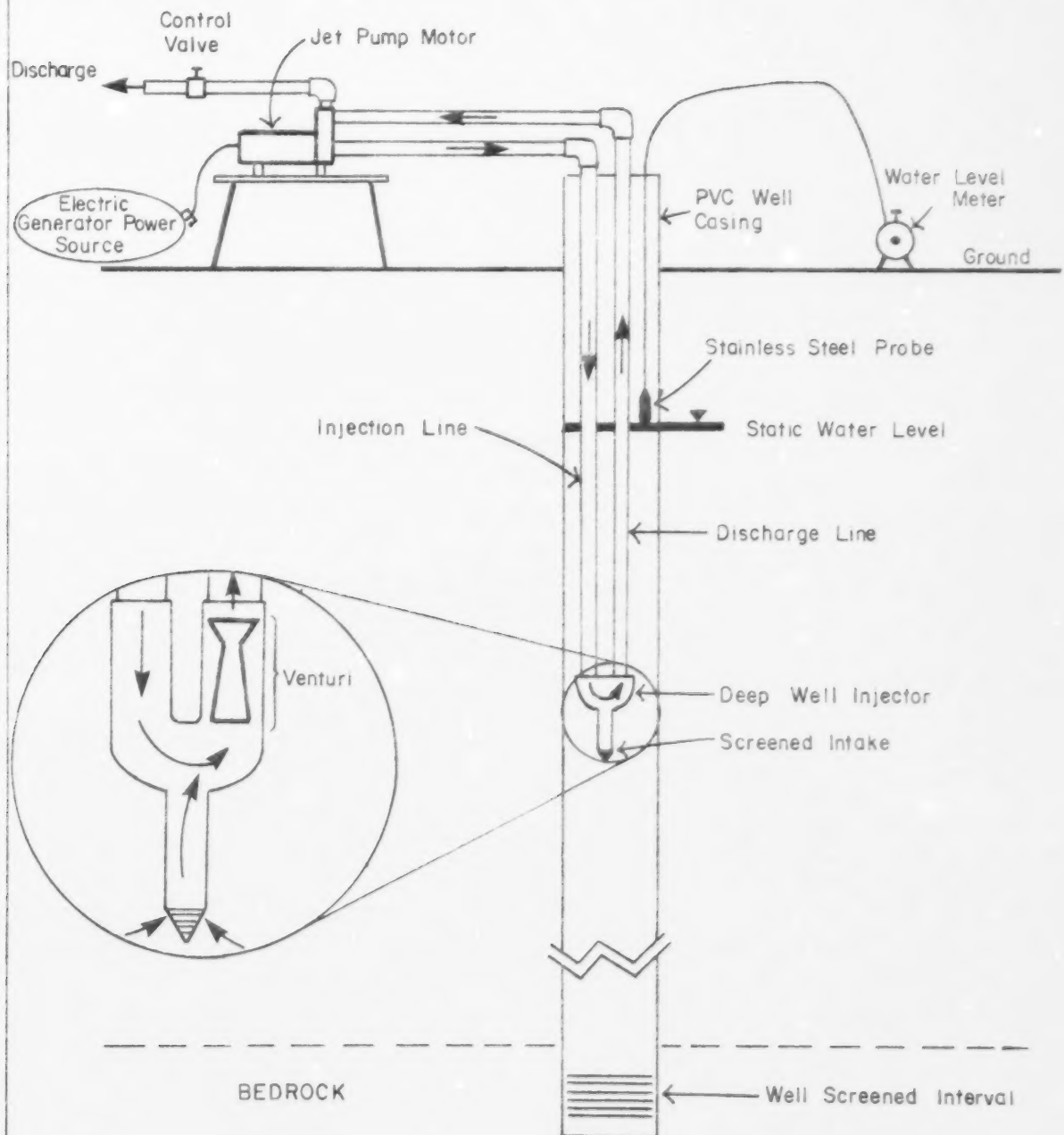
A3.4.2 EQUIPMENT

Pump testing was conducted using a narrow diameter pump to accommodate the inside diameter of the well casing. The pump selected for the pump test was a Jacuzzi jet pump (Model No. 15JH-S2). This pump was fitted with a 76 mm diameter deep well injector. The injector was installed to a depth of 15.3 m from ground surface, or about 5 m below the static water level in the well. The pump and injector assembly is shown in Figure A3-5. A 220 Volt portable electric generator was used as a power source for the pump.

A3.4.3 METHOD

Static water level measurements were taken at the pump well and all observation wells prior to testing. The observation wells included two shallow bedrock monitors (standard piezometers), two deep bedrock monitors (pneumatic piezometers), and one piezometer completed in the Lower Till Unit. In addition, water level measurements were taken at bedrock monitors at adjacent drilling locations.

Figure A3-5 Jet Pump Assembly



NOT TO SCALE

The pump and deep well injector were assembled as shown in Figure A3-5. Water taken from a nearby observation well was used to prime the pump. The water discharge hose was fitted with a control valve to regulate the pump discharge rate. Water from the well was discharged to an adjacent ditch during the pump test.

The pump was initially tested to check its operating performance and to adjust the discharge valve for the optimum discharge rate. The pump operated most efficiently under a slight back pressure with a pump rate of 0.72 L/s. Water level measurements were taken at the pump well during the initial set up test to establish potential drawdowns during the long term pump test. Adjustments were made to the depth of the injector to ensure that it would remain below the pumping water level in the well during the testing interval.

The water levels in the pump well and observation wells were allowed to recover to the initial static water levels prior to undertaking a trial pump test.

A trial pump test of one hour duration was initially conducted to determine well performance. Analysis of the test data from the pump well and the two bedrock observation wells suggested that the expected drawdown would remain relatively small during a long term pump test. The water levels were again allowed to recover to static.

The actual pump test was conducted over 18.2 h. Initially, water level measurements were taken at 10 s intervals in the pump well and the two shallow bedrock observation wells. Subsequent measurements were taken at progressively longer time

intervals. Toward the end of the pump test water level readings were taken every hour. The water level data were recorded on a Pump Test Form, an example of which is presented as Figure A3-6.

Temperature, pH, and conductivity were measured periodically on the discharge water, and pump flow rate measurements were recorded on the Pump Test Form. The flow rate was measured by recording the time required for the discharge water to fill a graduated container. Three water samples were collected during the pump test, one near the beginning of the test, another about halfway through the test and the last near the end of the test. These samples were retained in the event that chemical analysis was required.

Upon termination of the pump test, the recovery of the water level was measured in the observation wells. Measurements were taken at the same time intervals as during the pump test. The measurements were discontinued following recovery of the water levels. The tubing and injector were left in the pump well during the recovery period. The pump maintained its prime during the recovery and backflow of water into the pump well was negligible.

A3.5 LABORATORY TESTING

A3.5.1 INTRODUCTION

Laboratory tests were performed on soil samples to determine their hydraulic conductivity. A total of fifteen Shelby tube samples were tested. These are identified in Table A3-1, along with the depth and geologic unit from which the sample was collected. The laboratory tests were undertaken at Golder

FIGURE A3-6

Pump Test

PROJECT NO.

WELL NO.

[illegible]

TABLE A3-1: SAMPLES USED FOR LABORATORY PERMEABILITY TESTING

BOREHOLE NUMBER	SAMPLE NUMBER	SAMPLE DEPTH (m)	GEOLOGIC UNIT *	CONFINING PRESSURE (kPa)**
85-1-8	2	3.66- 4.27	UG	45
85-1-2	11	9.60-10.21	H	100
85-1-2	17	15.24-15.85	H	160
85-1-2	26	24.84-25.45	LG	260
85-3-2	15	18.30-18.90	LG	190
85-3-2	20	25.90-26.50	LT	270
85-8-8	2	3.61- 4.22	UG	45
85-8-8	6	21.95-22.56	LG	230
85-10-2	16	15.70-16.30	H	160
85-10-2	24	24.80-25.40	LG	260
85-12-8	1	3.05- 3.66	UG	45
85-12-8	3	10.67-11.26	H	110
85-12-22	2	15.85-16.46	H	160
85-12-8	5	21.34-21.95	H	230
85-12-22	4	28.04-28.65	LG	320

***NOTE:**

UG = Upper Glaciolacustrine Unit

H = Halton Unit

LG = Lower Glaciolacustrine Unit

LT = Lower Till

** kPa = Kilopascals

Associates (Eastern Canada) Limited geotechnical laboratory.

A3.5.2 EQUIPMENT AND METHOD

Two small, cylindrical test samples were extracted from each of the Shelby tube samples listed in Table A3-1. One test sample was cut parallel to the borehole axis (vertically oriented), while the other was cut perpendicular to the borehole axis (horizontal orientation). The two orientations were used to assess any anisotropy that might exist in the materials. Each test sample was then placed in a constant head permeability testing apparatus and tested under confining pressures that correspond to the effective overburden pressures, presented in Figure 6-1 of Section 6.0. The values used for each sample are indicated in Table A3-1. The detailed testing methodology is described in Golder Associates' report (dated July 1986) presented in Appendix G5.

A4 GEOTECHNICAL TESTING

Geotechnical soil testing was conducted by the testing laboratory of Golder Associates (Eastern Canada) Limited in Mississauga, Ontario. A variety of tests were completed on soil samples using standard American Society of Testing Materials (ASTM) testing procedures. A discussion of the types of soil testing performed and their procedures is provided in Appendix E1.

B-1

APPENDIX B
GROUND WATER SAMPLING
AND
ANALYTICAL PROTOCOLS

**APPENDIX B
GROUND WATER SAMPLING
AND ANALYTICAL PROTOCOLS**

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B1 GROUND WATER SAMPLING

B1.1 INTRODUCTION

This appendix describes the monitor flushing and ground water sampling practices used during the Phase 4B geoscience program. Flushing of the monitors was undertaken prior to sampling and involved the removal of stagnant water from the monitor casing to allow representative ground water from the surrounding geologic unit to flow into the monitor. Flushing procedures are described in Section B1.2. Ground water samples were collected from 36 monitors on two occasions, June 1986 and late August/early September 1986, for analysis of general chemical indicators (e.g. pH, total dissolved solids), major and minor ions, dissolved organic carbon, methane, and the isotopes tritium, oxygen-18 and deuterium. Two samples were also collected near the base of the overburden for carbon-14 dating and one sample from the bedrock for a organic "priority pollutant" scan. Ground water sampling techniques are outlined in Appendix B1.4.

Ground water samples were also collected for analysis of oxygen-18, deuterium and chloride by pore water squeezing of selected soil samples. The pore water squeezing techniques are described in Appendix B1.5. Also described are Analytical Methods (Appendix B2) and the Quality Assurance/ Quality Control program (Appendix B3).

B1.2 GROUND WATER MONITOR FLUSHING PROCEDURES

All monitors were flushed prior to sampling. The purpose of flushing was to remove stagnant water standing in the monitor casing, allowing representative ground water from the surrounding geologic unit to flow into the monitor. Table B1-1 provides details on the flushing and sampling program including monitor #, average well bore volume, the date when each monitor was flushed and the amount of ground water removed during flushing and the parameters analyzed. Two different flushing methods were utilized depending on the diameter of the monitor casing. Table B1-2 identifies the method used for each monitor. Descriptions of the flushing methods are provided in the following sections.

B1.2.1 FLUSHING METHOD A

A "Waterra" hand pump was used for flushing the 51 mm diameter monitors. This pump consists of a 25 mm diameter by 150 mm long foot valve made of Delrin attached to 12.7 mm I.D. polyethylene tubing (Figure B1-1). Water is drawn to surface with this pump by oscillating the tubing up and down by hand. This draws in successive aliquots of water past the foot valve and eventually results in the discharge of water at surface.

A separate dedicated pump was installed in each monitor. In overburden monitors, the foot valve was located within about 0.1 m of the bottom of the monitor (i.e. within the screened interval). In the bedrock monitors, the foot valve was located at depths of between 22 to 23 m, or about 9 to 10 m from the bottom of the monitor. The foot valve was not placed at the bottom of the bedrock monitors because of potential depth limitations of the pump flexible polyethylene tubing.

TABLE B1-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE WELL BORE VOLUME (L)	DATE	Activity F = Flushed S = Sampled	Water Level before Activity (m below top of pipe)	Water Level after Activity (m below top of pipe)	Approximate volume of Water Removed (L)	PARAMETERS ANALYSED
85-1-1	70.4	17-Apr-86	F	9.58	9.58	120.00	normal tritium
		17-Apr-86	S	9.58	9.58	0.02	
		12-May-86	F	9.70	9.70	120.00	
		17-Jun-86	F	9.68	9.68	120.00	list A
		17-Jun-86	S	9.68	9.68	2.18	
		20-Aug-86	F	9.94	9.97	120.00	
		26-Aug-86	F	9.91	9.91	120.00	
		26-Aug-86	S	9.91	9.91	2.07	list A & CH4
		18-Sep-86	F	9.89	9.89	120.00	
		18-Sep-86	S	9.89	9.89	0.60	CH4 & enriched trit.
85-1-3	6.4	14-Apr-86	S	7.79		0.02	normal tritium
		17-Apr-86	F	7.83	22.80	4.50	
		30-Apr-86	F	11.60	24.57	4.00	
		06-May-86	F	16.63	24.02	2.25	
		12-May-86	F	16.81	25.64	2.60	
		23-May-86	F	13.90	23.55	3.00	
		29-May-86	F	16.48	24.02	2.30	
		17-Jun-86	S	10.12	2.18	2.18	list A & normal trit.
		30-Jul-86	F	10.53	24.89	4.30	
		30-Jul-86	S	10.53	0.02	0.02	normal tritium
85-1-10	16.5	26-Aug-86	S	10.97	1.07	1.07	list B
		18-Sep-86	S			0.60	CH4 & enriched trit.
		26-Mar-86	F	1.85	5.75	25.00	
		17-Apr-86	S			0.02	normal tritium
		06-May-86	F	1.68	4.38	25.00	
		23-May-86	F	1.66	5.24	26.00	
		17-Jun-86	S	1.68	2.18	2.18	list A & normal trit.
		30-Jul-86	F	1.86	5.30	30.00	
		26-Aug-86	S	1.97	1.07	1.07	list B
		18-Sep-86	S			0.10	CH4
85-1-11	2.5	29-May-86	F	2.44	9.32	2.10	
		17-Jun-86	S	2.23	2.18	2.18	list A & normal trit.
		30-Jul-86	F	3.69	9.57	1.20	
		30-Jul-86	S	3.69		0.02	normal tritium
		26-Aug-86	S	3.72		1.07	list B
		18-Sep-86	S			0.10	CH4

NOTE: 1 See last page of this table for explanation of list A and list B.

2 Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.

3 CH4 = Methane

TABLE B3-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE WELL BORE VOLUME (L)	DATE	Activity F = Flushed S = Sampled	Water Level before Activity (m below top of pipe)	Water Level after Activity (m below top of pipe)	Approximate volume of Water Removed (L)	PARAMETERS ANALYZED
B5-1-14	1.7	23-May-86	F	2.52	DRY	1.30	list A & normal trit.
		17-Jun-86	S	2.23		2.18	
		20-Aug-86	F	2.00	3.05	2.50	
		11-Sep-86	S	2.96		2.07	list B, no CH4
		18-Sep-86	S			0.10	CH4
B5-1-15	3.4	01-Apr-86	F	3.35	DRY	1.00	normal tritium
		17-Apr-86	S	3.20		0.02	
		23-May-86	F	2.22	DRY	3.00	list A & normal trit.
		17-Jun-86	S	2.28		2.18	
		20-Aug-86	F	2.04	3.57	4.00	
		11-Sep-86	S	2.74		2.07	list B & enr. trit., no CH4
		18-Sep-86	S			0.10	CH4
B5-1-16	6.2	01-Apr-86	F	2.86	DRY	4.00	normal tritium
		17-Apr-86	S	2.59		0.02	
		23-May-86	F	2.09	DRY	6.00	list A & normal trit.
		17-Jun-86	S	1.95		2.18	
		20-Aug-86	F	2.27	4.56	5.00	
		11-Sep-86	S	2.53		2.07	list B & enr. trit., no CH4
		18-Sep-86	S			0.10	CH4
		01-Apr-86	F	2.88	DRY	5.00	normal tritium
		17-Apr-86	S	2.68		0.02	
B5-1-17	8.3	23-May-86	F	2.14	DRY	6.50	list A & normal tritium
		17-Jun-86	S	1.98		2.18	
		20-Aug-86	F	2.21	5.21	7.00	
		11-Sep-86	S	2.47		2.07	list B & enr. trit., no CH4
		18-Sep-86	S			0.10	CH4
		01-Apr-86	F	6.19	DRY	0.90	normal tritium
		17-Apr-86	S	6.15		0.02	
		23-May-86	F	5.13	6.22	3.00	list A & normal tritium
B5-1-18	2.1	17-Jun-86	S	5.36		2.18	
		20-Aug-86	F	4.10	6.24	4.50	
		11-Sep-86	S	5.32		1.82	list B & enr. trit., no CH4
		18-Sep-86	S			0.10	CH4

NOTE: # See last page of this table for explanation of list A and list B.

Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.

CH4 = Methane

TABLE B1-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE WELL BORE VOLUME (L)	DATE	Activity F = Flushed S = Sampled	Water Level before Activity (# below top of pipe)	Water Level after Activity (# below top of pipe)	Approximate volume of Water Removed (L)	PARAMETERS ANALYZED
B5-1-19	4.5	01-Apr-86	F	5.81	DRY	2.25	normal tritium
		17-Apr-86	S	6.16		0.02	
		23-May-86	F	4.85	6.69	3.70	list A & normal tritium
		17-Jun-86	S	5.51		2.18	
		20-Aug-86	F	3.97	6.74	5.00	list B & enr. trit., no CH4
		11-Sep-86	S	5.60		2.07	
		18-Sep-86	S			9.10	CH4
B5-1-20	9.1	01-Apr-86	F	4.42	7.43	5.75	normal tritium
		17-Apr-86	S	5.20		0.02	
		23-May-86	F	3.23	7.32	8.00	list A & normal tritium
		17-Jun-86	S	3.73		2.18	
		20-Aug-86	F	2.35	7.35	11.00	list B & enr. trit., no CH4
		11-Sep-86	S	3.53		2.07	
		18-Sep-86	S			0.10	CH4
B5-1-21	9.3	01-Apr-86	F	5.77	8.25	5.25	normal tritium
		17-Apr-86	S	6.96		0.02	
		23-May-86	F	4.83	8.31	7.00	list A & normal tritium
		17-Jun-86	S	6.06		2.18	
		20-Aug-86	F	4.04	8.30	9.00	list B & enr. trit., no CH4
		11-Sep-86	S	6.12		2.07	
		18-Sep-86	S			0.10	CH4
B5-2-4	4.0	29-May-86	F	3.15	15.04	3.60	list A & normal tritium
		12-Jun-86	S	6.02		1.68	
		30-Jul-86	F	5.08	15.25	3.00	normal tritium
		30-Jul-86	S	5.18		0.02	
		26-Aug-86	S	6.55		3.14	list A & enr. trit., no CH4
		18-Sep-86	S			0.60	CH4 & enriched trit.

NOTE: # See last page of this table for explanation of list A and list B.

Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.

CH4 = Methane

TABLE B1-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE WELL ZONE VOLUME (L)	DATE	Activity F = Flushed S = Sampled	Water Level before Activity (to below top of pipe)	Water Level after Activity (to below top of pipe)	Approximate volume of Water Removed (L)	PARAMETERS ANALYZED
B5-3-1	53.2	15-Apr-86	F	9.41	9.53	120.00	normal tritium
		15-Apr-86	S	9.41		0.02	
		07-May-86	F	9.47	9.64	120.00	
		12-Jun-86	F	9.57		120.00	List A
		12-Jun-86	S	9.57		2.18	
		20-Aug-86	F	9.74	9.80	120.00	
		26-Aug-86	F	9.72	9.72	120.00	List A & CH4
		18-Sep-86	F	9.69	9.69	2.07	
		18-Sep-86	S	9.69		120.00	
						0.60	CH4 & enriched trit.
B5-3-10	17.3	01-Apr-86	F	2.45	5.20	22.00	normal tritium
		17-Apr-86	S	2.19		0.02	
		06-May-86	F	1.92	4.13	24.00	
		22-May-86	F	1.83	4.65	25.00	List A & normal tritium
		12-Jun-86	S	1.44		2.18	
		30-Jul-86	F	1.56	4.98	30.00	
		26-Aug-86	S	1.73		1.07	List B CH4
		18-Sep-86	S			0.60	
B5-9-1	77.4	15-Apr-86	F	9.06		120.00	normal tritium
		15-Apr-86	S	9.06		0.02	
		06-May-86	F	9.16	9.17	120.00	
		18-Jun-86	F	9.18	9.19	120.00	List A
		18-Jun-86	S	9.18		4.35	
		20-Aug-86	F	9.36	9.39	120.00	
		21-Aug-86	F	9.44	9.44	120.00	List A & CH4
		18-Sep-86	S	9.44		3.64	
		18-Sep-86	F	9.38	9.38	120.00	
		18-Sep-86	S	9.38		0.60	CH4 & enriched trit.

NOTE: # See last page of this table for explanation of list A and list B.
 # Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.
 # CH4 = Methane

TABLE B1-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE WELL BORE VOLUME (L)	DATE	Activity	Water Level before Activity (# below top of pipe)	Water Level after Activity (# below top of pipe)	Approximate volume of Water Removed (L)	PARAMETERS ANALYZED
85-B-4	3.5	15-Apr-86	S	4.69		0.02	normal tritium
		17-Apr-86	F	4.73	14.13	2.80	
		30-Apr-86	F	6.42	14.02	2.30	
		06-May-86	F	8.33	15.04	2.00	
		12-May-86	F	8.81	15.49	2.00	
		23-May-86	F	6.82	14.20	2.20	
		29-May-86	F	8.35	14.82	2.00	
		18-Jun-86	S	4.50		2.18	
		30-Jul-86	F	6.14	14.75	2.00	
		30-Jul-86	S	6.14		0.02	
85-B-8	17.0	21-Aug-86	S	6.40		1.07	normal tritium list B CH4 & enriched trit.
		18-Sep-86	S			0.60	
		01-Apr-86	F	12.20	25.42	24.00	
		30-Apr-86	F	18.09	25.40	14.50	
		23-May-86	F	19.34	25.09	11.50	
		18-Jun-86	S	18.45		4.35	
		14-Jul-86	S			15.00	
		30-Jul-86	F	21.0	25.51	8.00	
		21-Aug-86	S	19.70		3.14	
		18-Sep-86	S			0.60	
85-B-10	13.7	01-Apr-86	F	2.69	5.44	20.50	normal tritium
		15-Apr-86	S	2.41		0.02	
		06-May-86	F	2.18	4.89	23.00	
		23-May-86	F	2.20	5.09	23.00	
		18-Jun-86	S	2.14		4.35	
		30-Jul-86	F	2.36	5.26	27.00	
		21-Aug-86	S	2.56		3.14	
		18-Sep-86	S			0.10	
		29-May-86	F	2.26	8.53	2.00	
		18-Jun-86	S	2.23		2.18	
85-B-11	2.5	30-Jul-86	F	3.02	8.78	1.80	list A & normal tritium normal tritium list B CH4
		30-Jul-86	S	3.02		0.02	
		21-Aug-86	S	3.33		1.07	
		18-Sep-86	S			0.10	

NOTE: # See last page of this table for explanation of list A and list B.

* Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.

* CH4 = Methane

TABLE B1-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE WELL BORE VOLUME (L)	DATE	Activity F = Flushed S = Sampled	Water Level before Activity (# below top of pipe)	Water Level after Activity (# below top of pipe)	Approximate volume of water removed (L)	PARAMETERS ANALYZED
85-10-1	92.3	15-Apr-86	F	8.31		120.00	normal tritium
		15-Apr-86	S	8.31		0.02	
		12-May-86	F	8.45	8.45	120.00	list A
		12-Jun-86	F	8.38	8.39	120.00	
		12-Jun-86	S	8.38		2.18	
		20-Aug-86	F	8.63	8.63	120.00	
		26-Aug-86	F	8.66	8.66	120.00	list A & CH4
		26-Aug-86	S	8.66		2.07	
		18-Sep-86	F	8.62	8.62	120.00	CH4 & enriched trit.
		18-Sep-86	S	8.62		0.60	
85-10-10	17.4	01-Apr-86	F	0.76	5.52	32.00	normal tritium
		15-Apr-86	S	0.84		0.02	
		07-May-86	F	1.25	4.32	28.00	list A
		23-May-86	F	0.83	5.09	31.00	
		12-Jun-86	S	0.94		2.18	
		30-Jul-86	F	1.40	5.15	30.00	
		26-Aug-86	S	1.57		1.07	list B CH4
		18-Sep-86	S			0.10	
		29-May-86	F	4.38	16.12	3.50	list A & normal tritium
		12-Jun-86	S	5.80		2.18	
85-11-4	4.2	30-Jul-86	F	7.65	16.43	2.70	normal tritium
		30-Jul-86	S	7.65		0.02	
		26-Aug-86	S	6.34		1.07	list B CH4 & enriched trit.
		18-Sep-86	S			0.60	

NOTE: # See last page of this table for explanation of list A and list B.

* Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.

† CH4 = Methane

TABLE B1-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE WELL BORE VOLUME (L)	DATE	Activity F = Flushed S = Sampled	Water Level before Activity (# below top of pipe)	Water Level after Activity (# below top of pipe)	Approximate volume of Water Removed (L)	PARAMETERS ANALYZED
85-12-1	82.2	15-Apr-86	F	8.43	8.46	120.00	normal tritium
		15-Apr-86	S	8.43		0.02	
		12-May-86	F	8.85	8.56	120.00	
		10-Jun-86	F	8.53		120.00	list A
		10-Jun-86	S	8.53		4.35	
		02-Jul-86	F	8.68		120.00	
		02-Jul-86	S	8.68		2.20	see FOOTNOTE 1
		20-Aug-86	F	8.81	8.83	120.00	
		21-Aug-86	F	8.79	8.79	120.00	list A & CH4
		18-Sep-86	F	8.73	8.73	120.00	
85-12-8	10.4	18-Sep-86	S	8.73		0.60	CH4 & enriched trit.
		20-Mar-86	F	18.04	25.09	14.00	
		29-Apr-86	F	15.89	25.30	18.00	
		23-May-86	F	18.77	25.02	12.50	
		10-Jun-86	S	19.80		4.35	list A & norm. trit.
		14-Jul-86	S			15.00	Carbon 14, 13 & norm. trit.
		30-Jul-86	F	20.19	25.22	10.00	
		21-Aug-86	S	19.24		3.14	list B
		18-Sep-86	S			0.60	CH4 & enriched trit.
85-12-10	17.5	26-Mar-86	F	1.18	5.38	37.00	normal tritium
		15-Apr-86	S	1.10		0.02	
		07-May-86	F	1.16	4.16	28.00	
		23-May-86	F	1.17	4.85	28.00	
		10-Jun-86	S	1.14		4.35	list A
		30-Jul-86	F	1.46	4.97	27.00	
		21-Aug-86	S	1.70		3.14	list B
		18-Sep-86	S			0.10	CH4

NOTE: ‡ See last page of this table for explanation of list A and list B.

‡ Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.

‡ CH4 = Methane

FOOTNOTE 1 : Scan for volatile and extractable, organic parameters on the U.S. E.P.A. priority pollutant list.

TABLE B1-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE WELL BORE VOLUME (L)	DATE	Activity	Water Level before Activity (# 25 cm top of pipe)	Water Level after Activity (# below top of pipe)	Approximate volume of Water Removed (L)	PARAMETERS ANALYZED
85-12-11	2.5	29-May-86	F	1.87	9.76	2.50	list A & normal tritium normal tritium list B CH4
		16-Jun-86	S	1.77		2.18	
		27-Jul-86	F	1.94	9.82	1.80	
		20-Jul-86	S	3.94		0.60	
		26-Aug-86	S	3.44		1.07	
85-12-13	1.2	18-Sep-86	S			0.10	normal tritium part of list A part of list B
		26-Mar-86	F	1.22	DRY	2.00	
		15-Apr-86	S	1.58		0.02	
		22-May-86	F	1.25	DRY	1.50	
		10-Jun-86	S	1.60		1.00	
85-12-14	4.0	16-Jun-86	S	1.60	DRY	0.50	normal tritium list A list B, no CH4 CH4
		20-Aug-86	F	1.71			
		11-Sep-86	S	DRY			
		26-Mar-86	F	1.08	DRY	5.20	
		15-Apr-86	S	0.99		0.02	
85-12-15	5.7	22-May-86	F	1.16	2.96	3.50	normal tritium list A list B, no CH4 CH4
		10-Jun-86	S	1.19		2.18	
		29-Aug-86	F	1.89	3.06	3.00	
		11-Sep-86	S	2.16		1.07	
		18-Sep-86	S			0.10	
85-12-15	5.7	26-Mar-86	F	0.96	DRY	7.00	normal tritium list A list B, no CH4 CH4
		15-Apr-86	S	0.93		0.02	
		22-May-86	F	1.07	3.43	4.50	
		10-Jun-86	S	1.26		2.18	
		29-Aug-86	F	2.23	2.52	3.00	
85-12-15		11-Sep-86	S	2.30		1.07	list B, no CH4 CH4
		18-Sep-86	S			0.10	

NOTE: # See last page of this table for explanation of list A and list B.

Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.

CH4 = Methane

TABLE B1-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE	DATE	Activity	Water Level Before Activity	Water Level after Activity	Approximate volume of Water Removed	PARAMETERS ANALYZED
85-12-16	8.3	26-Mar-86	F	1.10	4.49	8.50	normal tritium
		15-Apr-86	S	0.99		0.02	
		22-May-86	F	1.12	4.43	4.50	list A
		10-Jun-86	S	1.31		2.18	
		29-Aug-86	F	2.32	4.44	4.50	list B, no CH4
		11-Sep-86	S	2.45		1.07	CH4
		18-Sep-86	S			0.10	
85-12-17	10.5	26-Mar-86	F	1.04	5.34	9.50	normal tritium
		15-Apr-86	S	1.02		0.02	
		22-May-86	F	1.11	5.26	8.30	list A
		10-Jun-86	S	1.34		2.18	
		29-Aug-86	F	2.41	5.39	5.50	list B, no CH4
		11-Sep-86	S	2.63		1.07	CH4
		18-Sep-86	S			0.10	
85-12-18	9.0	26-Mar-86	F	2.13	6.06	9.00	normal tritium
		15-Apr-86	S	2.53		0.02	
		22-May-86	F	2.80	5.96	8.30	list A
		10-Jun-86	S	2.38		2.18	
		02-Jul-86	S	2.01		1.00	low level enriched trit.
		29-Aug-86	F	2.11	6.00	7.50	list B, no CH4
		11-Sep-86	S	3.16		1.07	CH4
		18-Sep-86	S			0.10	
85-12-19	9.3	26-Mar-86	F	2.60	6.71	9.00	normal tritium
		15-Apr-86	S	3.27		0.02	
		22-May-86	F	1.98	6.60	9.30	list A
		10-Jun-86	S	3.09		2.18	
		02-Jul-86	S	2.53		1.00	low level enriched trit.
		29-Aug-86	F	2.19	6.74	10.00	list B, no CH4
		11-Sep-86	S	4.09		1.07	CH4
		18-Sep-86	S			0.10	

NOTE: # See last page of this table for explanation of list A and list B.
 # Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.
 # CH4 = Methane

TABLE B1-1 : SUMMARY OF FLUSHING AND SAMPLING ACTIVITIES

MONITOR #	AVERAGE WELL BORE VOLUME (L)	DATE	Activity F = Flushed S = Sampled	Water Level before Activity # below top of pipe	Water Level after Activity (# below top of pipe)	Approximate volume of Water Removed (L)	PARAMETERS ANALYZED
85-12-20	14.2	26-Mar-86	F	1.92	7.46	14.50	normal tritium list A low level enriched trit. list B, no CH4 CH4
		15-Apr-86	S	1.79		0.02	
		22-May-86	F	2.00	7.37	10.50	
		10-Jun-86	S	1.70		2.18	
		02-Jul-86	S	1.75		1.00	
		29-Aug-86	F	2.03	7.43	12.50	
		11-Sep-86	S	2.36		1.07	
		18-Sep-86	S			0.10	
85-12-21	14.8	26-Mar-86	F	2.51	7.69	14.50	normal tritium list A low level enriched trit. list B, no CH4 CH4
		15-Apr-86	S	2.66		0.02	
		22-May-86	F	1.66	8.26	13.20	
		10-Jun-86	S	2.39		2.18	
		02-Jul-86	S	2.12		1.00	
		29-Aug-86	F	2.32	8.40	13.00	
		11-Sep-86	S	3.30		1.07	
		18-Sep-86	S			0.10	

NOTE: # See last page of this table for explanation of list A and list B.
 # Samples collected for list B required a smaller volume of water due to reduced parameters and laboratory requirements.
 # CH4 = Methane

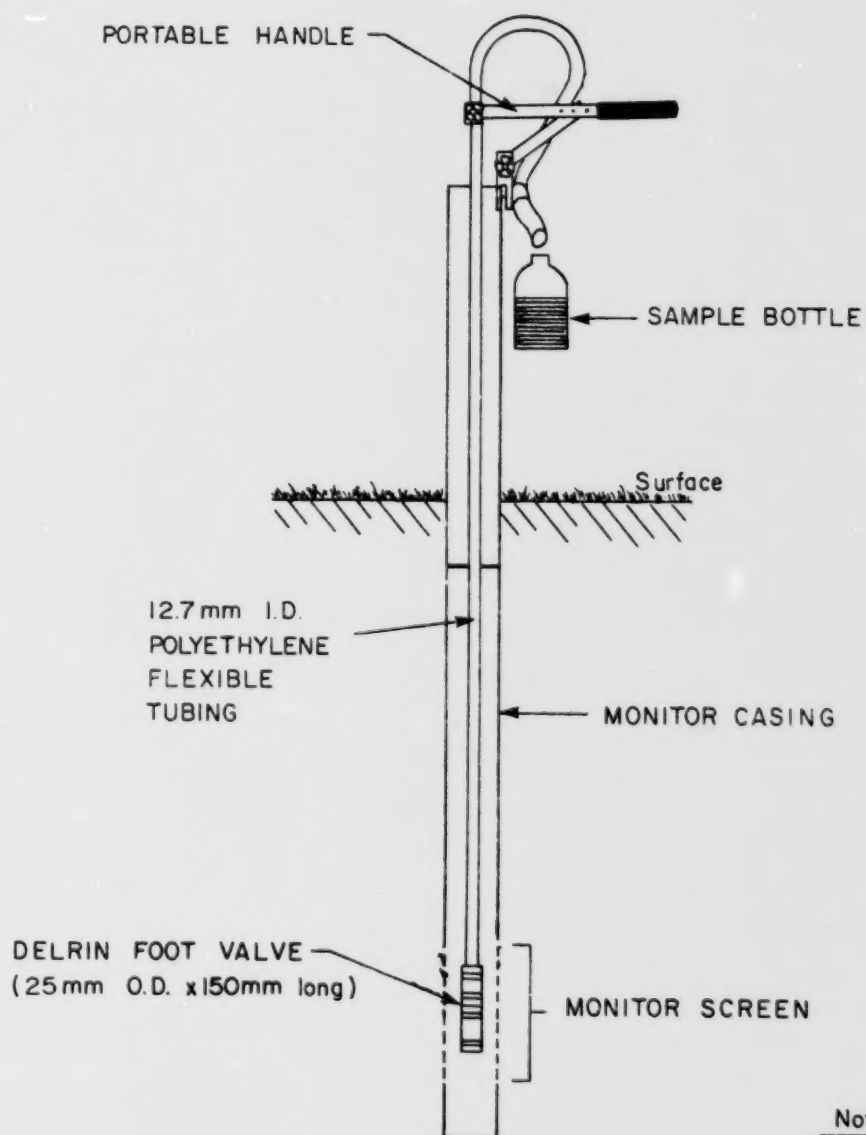
LIST A : ANALYSES -
 pH, alkalinity, total dissolved solids, dissolved inorganic carbon, dissolved organic carbon, sulphide, inductively coupled argon plasma scan for cations (As, Al, B, Ba, Be, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sr, Th, Ti, V, Zn, Zr) and ion chromatography scan for anions (F, Cl, NO3, NO2, PO4, Br, SO4), oxygen-18, deuterium.

LIST B : ANALYSES -
 All parameters listed in LIST A plus mercuric, except for oxygen-18 and deuterium.

TABLE B1-2: FLUSHING METHODS USED AT EACH MONITOR

Monitor #	Flushing Method	Monitor #	Flushing Method	Monitor #	Flushing Method
85-1-1	A	85-2-4	B	85-12-8	A
85-1-3	B	85-3-1	A	85-12-10	A
85-1-10	A	85-3-10	A	85-12-11	B
85-1-11	B	85-8-1	A	85-12-13	A
85-1-14	A	85-8-4	B	85-12-14	A
85-1-15	A	85-8-8	A	85-12-15	A
85-1-16	A	85-8-10	A	85-12-16	A
85-1-17	A	85-8-11	B	85-12-17	A
85-1-18	A	85-10-1	A	85-12-18	A
85-1-19	A	85-10-10	A	85-12-19	A
85-1-20	A	85-11-4	B	85-12-20	A
85-1-21	A	85-12-1	A	85-12-21	A

N.B. See Appendix B1.2 for explanation of flushing methods.

Figure B1-1**SCHEMATIC OF THE 'WATERRA'™
HAND PUMP**Not To Scale

Due to the low permeability of the overburden materials, most monitors in the overburden were flushed using the "Waterra" pump, by pumping until no more water could be discharged (i.e. pumped almost dry). A bailer was then used to remove the small amount of ground water remaining within the monitor. A small diameter (4.8 mm I.D.) polyethylene tube was then inserted inside and to the bottom of the tubing of the "Waterra" pump and nitrogen blown through this tube to remove the water remaining above the foot valve.

In the standpipes, where fracturing makes the near surface portion of the overburden more permeable, the monitors could not always be pumped dry. In this case the monitors were flushed by removing 21 to 30 L of water (about 1 to 2 well bore volumes).

The higher permeability of the bedrock aquifer also prevented monitors in the bedrock from being pumped dry. The bedrock monitors were flushed by removing 120 L of water (about 2 well bore volumes).

B1.2.2 FLUSHING METHOD B

Nitrogen was used for flushing the smaller 19 mm diameter monitors. Dedicated 6.4 mm I.D. polyethylene tubing was installed to the bottom of these monitors. Compressed nitrogen was then forced through this tubing, causing the ground water to rise up between the tubing and monitor casing and out of the top of the monitor. With this method, approximately 0.5 L of water remained in the monitor after flushing.

B1.3 CEMENT INTERFERENCES

Several water quality monitors had ground water with anomalously high pH (greater than 10). These monitors were: 85-1-8, 85-1-9,

85-3-8, 85-3-9, 85-8-9, 85-10-8, 85-10-9 and 85-12-9. Repeated flushings did not result in a reduction in pH.

The high pH values are likely the result of contamination by cement used to seal the upper portion of the boreholes. Ground waters in contact with partially set cement typically have very high pH values (Barcelona and Helfrich, 1986). The water quality monitors were sealed by placing a thick layer (4.1 to 7.5 m) of bentonite pellets in the borehole annulus above the screened interval. Above the bentonite pellets, cement grout was tremmied into place to seal the remainder of the borehole. Monitor construction details are described in Appendix A and tabulated in Appendix F. It appears that despite the thick bentonite seals, some of the cement penetrated through the pellets and into the area around the monitor screen. This likely occurred because of the dry condition of many of the deep overburden boreholes upon completion. As a result, the bentonite seals did not set prior to placement of the cement, nor did the fluids in the grout cause the pellets to set.

The monitors affected by cement were not used to collect ground water samples. Smaller diameter hydrogeologic monitors installed for water level measurements and hydraulic conductivity testing which were not influenced by grout, were sampled in place of the affected water quality monitors. Hydrogeologic monitors which were sampled are 85-1-3, 85-1-11, 85-2-4, 85-8-4, 85-8-11, 85-11-4 and 85-12-11.

B1.4 GROUND WATER SAMPLING PROCEDURES

Table B1-3 is a summary of the monitors at each location from which ground water samples were collected for chemical analysis. The monitoring locations are shown in Figure B1-2.

TABLE B1-3: SUMMARY OF MONITORS USED TO COLLECT GROUND WATER SAMPLES

DRILLING LOCATION	BEDROCK MONITORS	OVERBURDEN MONITORS
1	85-1-1	85-1-3, 85-1-10*, 85-1-11, 85-1-14, 85-1-15, 85-1-16, 85-1-17, 85-1-18, 85-1-19, 85-1-20, 85-1-21
2		85-2-4
3	85-3-1	85-3-10*
8	85-8-1	85-8-4, 85-8-8, 85-8-10*, 85-8-11
10	85-10-1	85-10-10*
11		85-11-4
12	85-12-1	85-12-8, 85-12-10*, 85-12-11, 85-12-13, 85-12-14, 85-12-15, 85-12-16, 85-12-17, 85-12-18, 85-12-19, 85-12-20, 85-12-21

* these monitors are standpipes screened from above the water table to a depth of approximately 5.3 m.

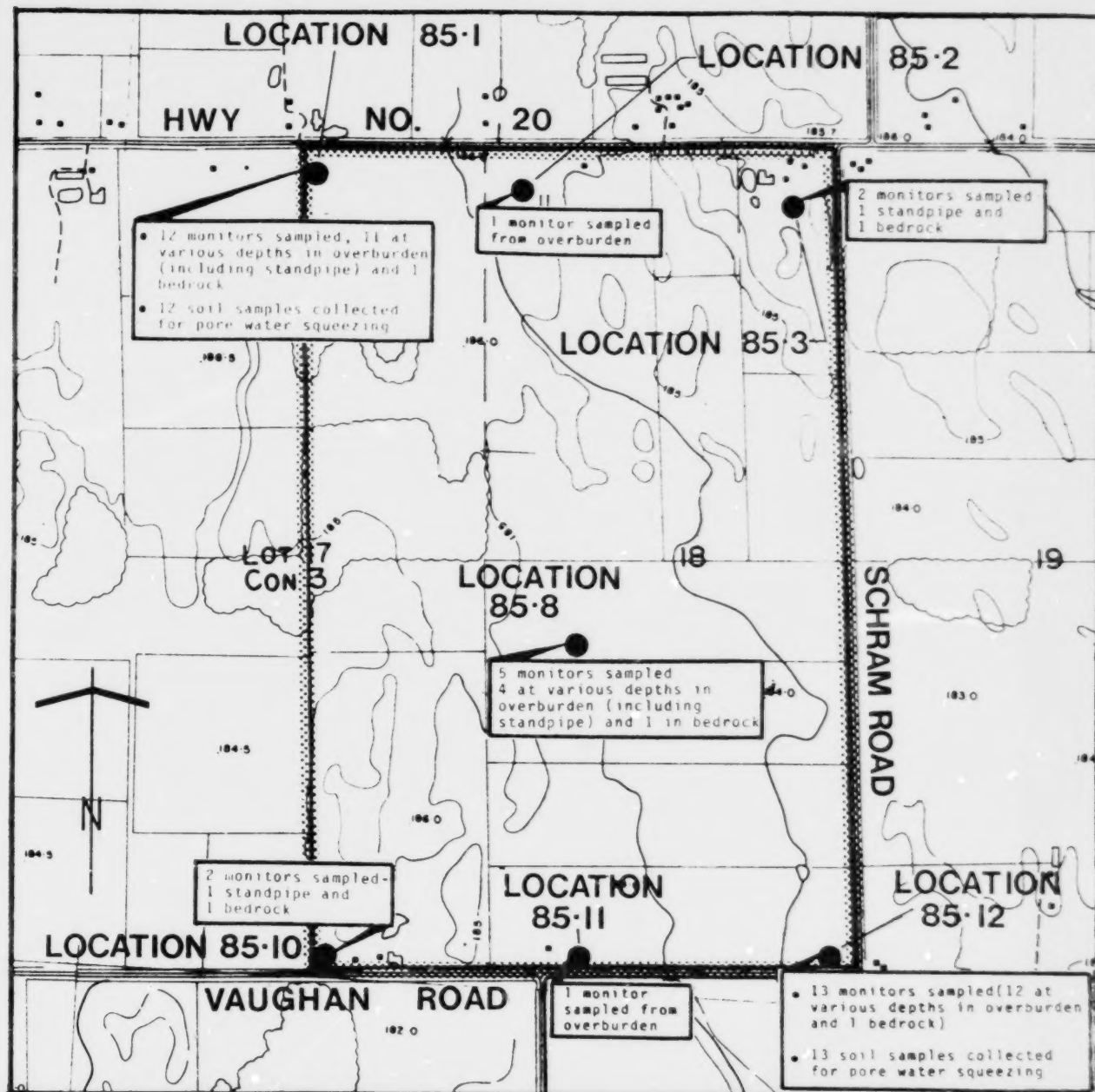


Figure B1-2
GROUND WATER SAMPLING LOCATIONS

Boundary

Sampling Location

0 500 metres
 SCALE

NOTE: See appendix A1 and figure for details of each site

Ground water samples were collected from the overburden monitors approximately three weeks after flushing. Due to the low permeability of the overburden materials, an interval of three weeks was required prior to sampling to allow a sufficient volume of ground water to flow into the monitor.

Due to the higher permeability of the bedrock, bedrock monitors were sampled immediately after flushing.

The majority of ground water samples were collected on two occasions: (1) over the period June 10 to 18, 1986 and, (2) on one of the following three days; August 21, August 26 and September 11, 1986. Occasional samplings of selected monitors for selected parameters were undertaken at other times. Table B1-1 summarizes when samples were collected from each monitor and for which parameters. The results of the chemical analyses conducted on the ground water samples are tabulated in Tables J-1 to J-4 in Appendix J.

Prior to sampling, the water level was measured and the volume of water in the monitor calculated. Approximately 3 L of ground water was required for rinsing the bottles and equipment, measuring temperature, conductivity and pH, and the sample.

Three different sampling methods were used to collect ground water samples depending on the diameter of the monitor casing and formation permeability. The method used for each monitor is listed in Table B1-4. Descriptions of the sampling methods are provided in the following sections. Also described is a separate sampling technique employed by Mr. B. Drimmie of the Isotope Laboratory, University of Waterloo to collect samples for Carbon

TABLE B1-4: SUMMARY OF SAMPLING METHODS USED AT EACH MONITOR

MONITOR #	SAMPLING METHOD	MONITOR #	SAMPLING METHOD	MONITOR #	SAMPLING METHOD
85-1-1	B	85-2-4	C	85-12-8	B
85-1-3	C	85-3-1	B	85-12-10	A
85-1-10	A	85-3-10	A	85-12-11	A
85-1-11	C	85-8-1	B	85-12-13	C
85-1-14	A	85-8-4	C	85-12-14	A
85-1-15	A	85-8-8	A	85-12-15	A
85-1-16	A	85-8-10	A	85-12-16	A
85-1-17	A	85-8-11	C	85-12-17	A
85-1-18	A	85-10-1	B	85-12-18	A
85-1-19	A	85-10-10	A	85-12-19	A
85-1-20	A	85-11-4	C	85-12-20	A
85-1-21	A	85-12-1	B	85-12-21	A

14 and 13 analyses. As well, the filtering, preservation, transportation and chain of custody protocols are outlined.

B1.4.1 SAMPLING METHOD A

A 25 mm O.D. stainless steel bailer on a wire line was used to collect ground water samples from the 51 mm diameter monitors in the overburden. The first few samples were discarded. The next sample was used to fill a beaker for immediate measurement of temperature, conductivity and pH. Sample bottles were filled after first rinsing each bottle with the water being sampled. Between monitors, the bailer was rinsed with distilled water and dried with a clean J-cloth.

B1.4.2 SAMPLING METHOD B

Ground water samples were collected from the bedrock monitors using the dedicated "Waterra" pumps which were installed in each monitor. Use of this pump is described in Appendix B1.2.1. Immediately prior to sampling, the monitors were flushed by pumping out about 120 L of water. A beaker was then filled for immediate measurement of temperature, conductivity and pH. Ground water was then collected directly into the sample bottles from the pump outlet, after first rinsing each bottle with the water being sampled.

B1.4.3 SAMPLING METHOD C

In order to sample the smaller 19 mm diameter monitors the dedicated 6.4 mm tubing was first removed and a 15 mm O.D. by 55 mm long polyethylene check valve was attached to the end of this tubing. The tubing/check valve was re-inserted to the bottom of the monitor. The tubing containing ground water from the monitor, was then pulled from the monitor. The check valve prevents the ground water sample from draining out of the

tubing. The positive pressure end of a peristaltic pump was then attached to the check valve and the water forced out the opposite end of the tubing for sample collection. This procedure was repeated until sufficient volume of sample was collected. The first 250 mL of water from each tube was discarded. The next 100 to 200 mL of the first tube was poured into a beaker for immediate measurement of temperature, conductivity and pH. The remaining water was used to fill the sample bottles, after first rinsing each bottle with the water to be sampled.

Whenever tubing was removed from the monitor, care was taken to prevent the tubing from contacting the ground. This reduced the possibility of extraneous material from getting into the monitor.

Sampling Method C was also used for the larger diameter monitors to collect samples for methane analysis because this method minimizes the loss of volatile gases.

B1.4.4 CARBON ISOTOPE SAMPLING

Two samples were collected from monitors 85-12-8 and 85-8-8 for carbon-14 and carbon-13 isotope analyses on the natural carbonate which is dissolved in the water. These samples were collected on July 14, 1986 by Mr. Bob Drimmie of the Isotope Laboratory, Department of Earth Sciences, University of Waterloo. The sampling procedure was as follows:

- (1) The ground water samples were collected in 20 L collapsible plastic jugs. Collapsible jugs were used because only 15 to 16 L could be obtained from each monitor. By collapsing the jug prior to sampling, minimal headspace or air contact resulted after filling even with a volume of water smaller than the 20 L jug capacity.

- (2) Prior to sampling, the plastic jug was rinsed as follows: once with a 10% hydrochloric acid solution to remove any traces of carbonate; once with deionized, carbonate free water; and once with the water being sampled. The jug was then collapsed to remove as much air as possible.
- (3) Ground water was removed from the monitor and poured into the sample jug using a gas driven squeeze pump. The operation of this type of pump is described by Scalf et al. (1981). The monitors were pumped dry to obtain as much water as possible.
- (4) Once the jug was full, NaOH was immediately added to raise the pH to between 11 and 12. The pH was measured in the field to confirm this.
- (5) A precalculated amount of $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ was then added immediately. The amount of $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ was precalculated based on alkalinity and sulphate values previously determined on ground water samples from these monitors. The amount of $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ added was 20% in excess of that required to precipitate all carbonate and sulphate dissolved in the sample water.
- (6) The sample jug was then capped tightly and shaken.
- (7) Samples were then transported back to the Isotope Laboratory at the University of Waterloo.
- (8) The precipitate was allowed to settle overnight.
- (9) The water was siphoned out until only the precipitate

and about 1 L of water remained. Note that the jug collapses as the water is removed, preventing air contact.

- (10) The remaining precipitate and 1 L of water were then poured into a 1 L bottle with no headspace. Some air contact occurs here but the bias is considered to be minimal for dissolved carbonate younger than about 30,000 years. If bias occurs it would make the dissolved carbonate appear younger than its actual age. (personal communication with Bob Drimmie, University of Waterloo, Isotope Laboratory)
- (11) To neutralize the pH, the precipitate and associated water were then rinsed several times with boiled, carbon dioxide free, distilled water.
- (12) The precipitate and water were then placed in two 20 mL bottles, with no headspace. One bottle, containing approximately two-thirds of the precipitate was used for carbon-14 counting. The other bottle was used for carbon-13 analysis.

Despite the above precautions, contamination of the samples by modern carbon appears to have occurred. The source of contamination has not been identified but is likely from one of two sources, as described below.

- (1) Because of the low dissolved carbonate concentrations in the deep overburden ground waters (44 to 63 mg/L HCO_3) and the low permeability of materials, only a small amount of carbon was available for dating (1.9 to 3.7 mg). Because of the small amount the sample

may have been susceptible to contamination during laboratory preparation and counting. To minimize this effect, collection of a composite sample from several sampling runs is recommended to increase the amount of carbon available for dating.

- (2) To collect a sufficient volume of ground water in the low permeability materials, an interval of approximately 2 to 3 weeks was required for recovery after flushing. Geochemical speciation modelling of the ground waters at 25 m using WATEQF (Plummer et al., 1976), suggests that these deep ground waters have lower CO_2 partial pressures than the atmosphere. Consequently during the 2 to 3 week recovery period, it is anticipated that exchange and uptake of CO_2 from the atmosphere occurred. Because of the very low dissolved bicarbonate concentrations at 25 m depth (44 to 63 mg/L) it would not require much dissolved atmospheric CO_2 to significantly alter the ground water to appear near modern in age. These monitors should be resampled using a method that prevents exchange with CO_2 . The recommended protocol is to purge the air in the monitor with argon after flushing and then place a one holed rubber stopper with an Ascarite trap (CO_2 trap) in the top of the monitor to prevent atmospheric CO_2 from entering the monitor during recovery.

B1.4.5 SAMPLE FILTERING

For filtered samples, the collected ground water was poured into a 4 L plastic jug, from which it was drawn using a peristaltic pump and immediately pumped through the filter. A schematic of the filtering procedure is shown in Figure B1-3. The parameters for which samples were filtered are summarized in Table B1-5.

Figure B1-3
SCHEMATIC OF SET-UP FOR FILTERING
GROUND WATER SAMPLES

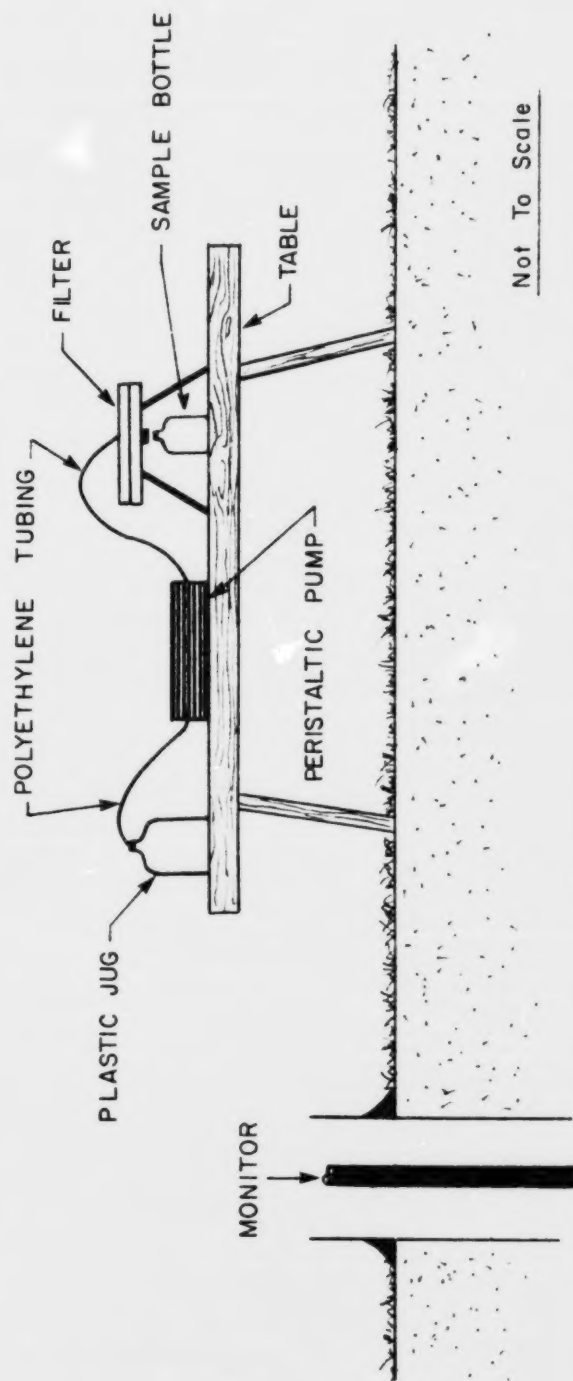


TABLE B1-5: SUMMARY OF BOTTLE TYPES AND PRESERVATIVES FOR GROUND WATER SAMPLES

FOR ANALYSIS OF:	BOTTLE TYPE	FILTERED	PRESERVATIVE	STORAGE, TRANSPORTATION CONDITIONS	COMMENTS	LABORATORY
anion chromatog- raphy, pH, total dissolved solids	250 mL or 500 mL plastic	yes	no	cool, dark		Barringer Magenta Ltd.
inductively coupled argon plasma scan	30 or 50 mL plastic	yes	5-10 drops of nitric acid	cool, dark		Barringer Magenta Ltd.
dissolved or- ganic carbon dissolved in- organic carbon	20 mL glass	yes	no	cool, dark		Barringer Magenta Ltd.
sulphide	500 mL plastic	no	2 mL zinc acetate and 1 mL sodium hydroxide	cool, dark		Barringer Magenta Ltd.
organic priority pollutant scan	100 mL amber for volatiles and 1 L amber for extract- ables	no	no	cool, dark	no headspace in volatile bottle	Mann Testing Labora- tories Ltd.
dissolved methane	100 mL amber glass with septum	no	no	cool, dark	no headspace	Mann Testing Labora- tories Ltd.
oxygen-18, Deuterium, enriched tritium	500 mL or 1 L glass	no	no	dark	no expos- ure to in- door atmo- sphere and fluores- cent dials	Isotope Laboratory, University of Waterloo
normal tritium	20 mL plastic	no	no	dark	as above	Isotope Laboratory, University of Waterloo
low level tritium	1 L glass	no	no	dark, poly- seal caps	as above	Rosentiel Isotope Laboratory, University of Miami, Florida
carbon-14, carbon-13	20 L collap- sible plastic jug	no	no	dark	precip- itated in field as BaCO	carbon-14 at Isotrache Laboratory, University of Toronto carbon-13 at Isotope Laboratory, University of Waterloo

B1.4.6 SAMPLE PRESERVATION AND TRANSPORTATION

Table B1-5 summarizes the types of sample containers and preservatives used for the various analytical parameters (except carbon-14 and carbon-13 which are described in Appendix B1.3.4). Sample bottles were provided pre-cleaned by the laboratories doing the analyses. Preservatives were also provided by the laboratories. After collection, all samples were immediately placed inside a cooler containing ice. Samples remained in the coolers until delivered to the laboratory for analysis. Samples were delivered to the laboratories within one to three days after sampling. Ice was replenished as required to keep sample temperature at about 4 °C.

B1.4.7 CHAIN OF CUSTODY AND FIELD RECORDS

All bottles were labelled in the field with the job, date, location, monitor, company name, sampler's name and preservatives added. All information such as water levels, water volume in monitor, pH, temperature, conductivity, colour, smell, clarity, bottles collected, filtration and weather conditions were recorded on Field Sampling Sheets (Figure B1-4)

Chain of custody forms were also completed listing the sample bottles, location and monitor, analyses to be undertaken, date sampled, sampler and company name, job, time and date of delivery to laboratory, name of laboratory, and the names of personnel delivering and receiving the samples. These forms are on file at Gartner Lee Limited.

B1.5 PORE WATER SQUEEZING

Soil samples were collected in shelly tubes from various depths at locations 85-1 and 85-12. The sample depths are listed in Table B1-6. The soil sampling and preservation protocols for shelly tubes are outlined in Appendix A1.3.2.

DATE _____ SAMPLED BY _____

Gartner Lee Limited

TABLE B1-6: SOIL SAMPLES COLLECTED FOR PORE WATER SQUEEZING

Location 85-1 - Samples were collected while drilling
borehole 85-1-22

<u>Shelby Tube #</u>	<u>Depth Interval (m)</u>
1	1.52 to 2.13
2	3.05 to 3.66
3	4.57 to 5.18
4	6.10 to 6.71
5	9.14 to 9.76
7	12.19 to 12.80
9	15.85 to 16.46
10	18.29 to 18.90
11	21.33 to 21.95
13	24.38 to 24.99
14	27.43 to 28.04
16	30.48 to 31.09

Location 85-12 - Samples were collected while drilling
borehole 85-12-12

<u>Shelby Tube #</u>	<u>Depth Interval (m)</u>
1	1.52 to 2.13
2	3.05 to 3.65
3	4.57 to 5.18
4	6.10 to 6.71
5	9.14 to 9.75
6	12.19 to 12.80
7	15.24 to 15.85
8	18.29 to 18.90
9	21.34 to 21.95
10	24.36 to 24.99
11	27.43 to 28.04
12	30.48 to 31.08
13	33.53 to 34.14

Pore waters were extracted from these soil samples at the Department of Earth Sciences, University of Waterloo, under the direction of Dr. S.K. Frappe and J. Rodvang. The pore water squeezing methodology as provided by the University of Waterloo is described below.

Squeezing was done using nine stainless steel cylinders connected in line to a tank of compressed nitrogen. Nitrogen pressure was increased gradually from 1380 kPa to a maximum of 5170 kPa. The pressure was regulated using a pressure transducer, to within 35 kPa.

Prior to being squeezed, cores were stored in waxed shelly tubes at 4° C. Upon removal from the shelly tubes for squeezing, the outer edges were trimmed from each core segment to remove parts which may have become contaminated. All parts of the squeezers were thoroughly rinsed with de-ionized water between runs, and squeezing was carried out at 4° C.

Each squeezer consisted of a hollow barrel fitted over a base (see Figure B1-5). A 65 mm long core segment was inserted into the barrel, and piston was placed on top. As pressure was applied to the piston, the clay was compressed, and water was squeezed from the pores. The water was filtered through two "Whatman 40" filter papers placed between the clay and the base before passing to a stainless steel collecting tube attached to the base. From there, the water flowed through a short segment of tygon tubing and into a 30 mL polyethylene sample bottle. A piece of parafilm stretched over the bottle prevented the water from evaporating while it was being collected. Each water sample was collected

B-36

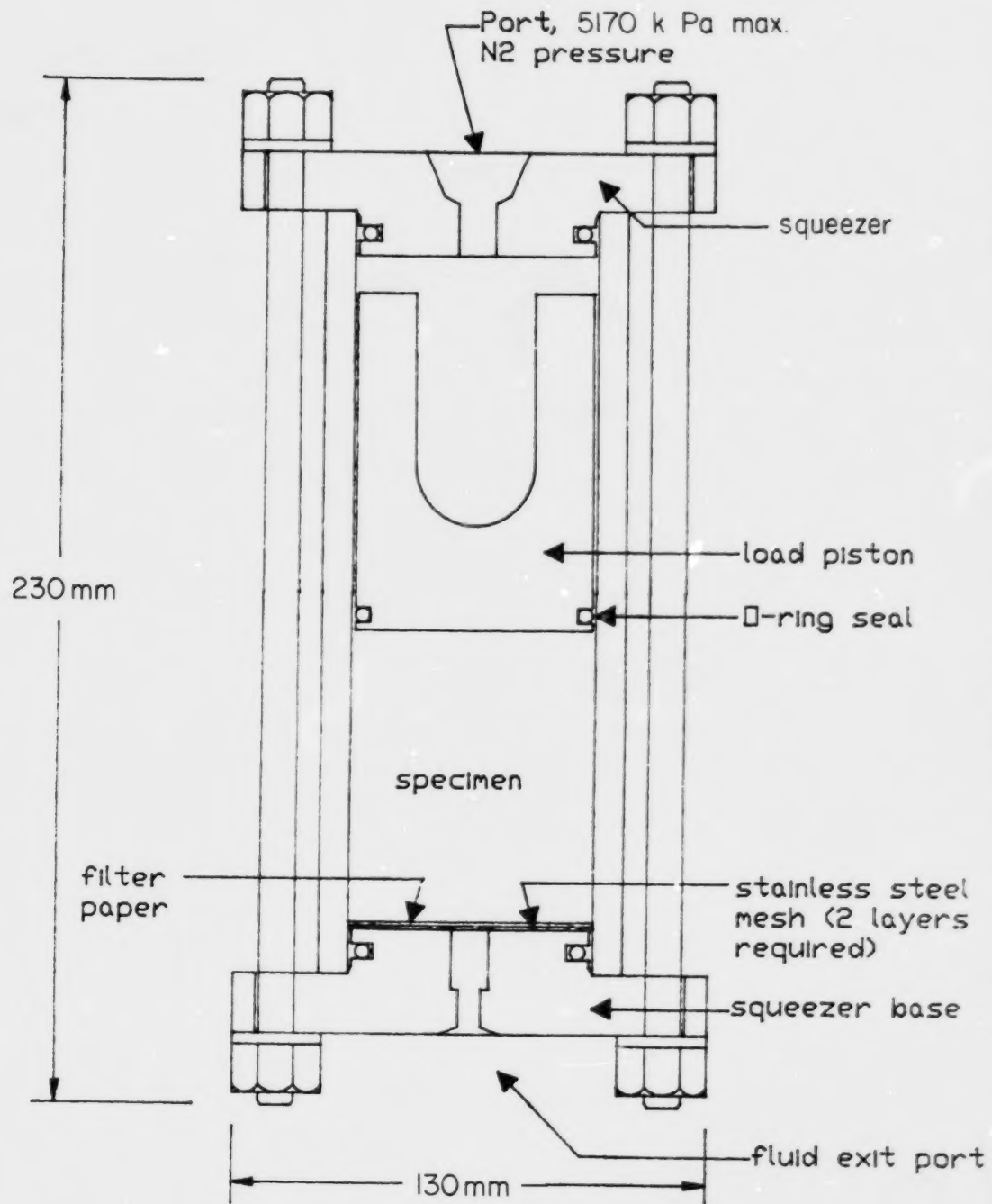


FIGURE B1-5 - Pore Fluid Extractor

Design: J. Baleshta
CAD: M. Jones

within approximately twenty-four hours. Sample bottles were then tightly capped and refrigerated until analysis

The collected pore water was analyzed for oxygen-18, deuterium and chloride. These results are summarized in Table J5 of Appendix J.

B2 ANALYTICAL METHODS

B2.1 FIELD MEASUREMENTS

B2.1.1 TEMPERATURE

Temperature measurements were made with a standard mercury thermometer after about two minutes equilibration.

For the first set of ground water samples (June 1986), temperature was measured on ground water poured into a beaker. The measurement was taken within a few minutes of being withdrawn from the monitor. However, this first method appeared to result in anomalous temperatures. Consequently, subsequent measurements were made by lowering the thermometer down the monitor on a string, into the ground water at screen level. A time period of few minutes was allowed for equilibration and then the thermometer was rapidly removed to obtain the reading. Measurements with the second method are considered to be most representative of ground water temperatures

B2.1.2 CONDUCTIVITY

Conductivity measurements were made on ground water samples using a model C45 LisleMetrix Minibridge conductivity meter. This meter provides automatic temperature compensation. Prior to each sampling run, the conductivity meter calibration was checked against standard solutions of known conductivity.

B2.1.3 pH

pH measurements were made with a Model #95 Markson Digital pH/mv/temperature meter.

Calibration of the pH meter was completed as follows:

- (1) Ground water was pumped from one of the monitors into a beaker. The beaker was placed in a cooler to maintain its temperature.
- (2) The calibration buffer solutions were immersed in this water to equilibrate them to ground water temperature. Equilibration took approximately 10 to 15 minutes. The temperature was then recorded.
- (3) The pH electrode was rinsed thoroughly with distilled water. Excess water was removed by shaking and touching the end with a clean tissue.
- (4) The pH electrode was immersed in the pH 7 buffer and the STANDARDIZE knob adjusted to a steady reading of the appropriate pH. Refer to Table B2-1 for standard buffer values at various temperatures. The solution was slowly stirred during measurement.
- (5) The pH electrode was rinsed as in (3).
- (6) The pH electrode was immersed in the pH 10 buffer and the TEMPERATURE knob adjusted to a steady reading of the appropriate pH. Refer to Table B2-1. The solution was slowly stirred during measurement.
- (7) The pH electrode was again rinsed as in (3).
- (8) The reading in the pH 7 buffer was checked and if this varied by more than 0.02 units recalibration was undertaken.
- (9) Calibration was undertaken three times daily.

TABLE B2-1: STANDARD BUFFER VALUES AT VARIOUS TEMPERATURES

TEMPERATURE (degrees C)	pH OF BUFFER SOLUTIONS		
	4.01	7.00	10.00
0	4.003	7.12	--
5	3.999	7.09	10.18
10	3.998	7.06	10.15
15	3.999	7.04	10.12
20	4.002	7.02	10.05
25	4.008	7.00	10.00
30	4.015	6.99	9.96

Sample pH measurements were completed as follows:

- (1) The pH electrode was rinsed as in (3) above.
- (2) Ground water from the monitors was pumped into a beaker where temperature and conductivity measurements were taken followed immediately by pH.
- (3) To take a measurement, the pH electrode was immersed in the ground water in the beaker until a relatively stable pH reading was obtained (about 15 minutes). The water was slowly stirred during measurement.
- (4) Periodically the electrode was checked with the pH 7 buffer. If the reading was not within 0.02 units of the proper pH 7 buffer value, the pH meter was recalibrated.

B.2.2 LABORATORY ANALYTICAL METHODS

The parameters analyzed and the laboratories where the analyses were undertaken are listed in Table B2-2.

The analytical methods used by each of the laboratories are summarized in Appendices B4.1 to B4.5, provided by the laboratories. Each attachment either outlines the analysis methodologies or gives a reference where each method is outlined and indicate any modifications made to the referenced methods. Also provided in Appendices B4.1 to B4.5 are chemical parameter detection limits.

**TABLE B2-2: PARAMETERS ANALYZED AND LABORATORIES
WHERE THE ANALYSES WERE COMPLETED**

LABORATORY	ANALYSES
1. Barringer Magenta Limited 304 Carlingview Drive, Rexdale, Ontario M9W 5G2 (416) 675-3870 (see Appendix B4.1)	pH, alkalinity, total dissolved solids, dissolved inorganic carbon, dissolved organic carbon, sulphide, inductively coupled argon plasma scan for cations (Ag, Al, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Si, Sr, Th, Ti, V, Zn, Zr), and ion chromatography scan for anions (F, Cl, NO₃, NO₂, PO₄, Br, SO₄)
2. Mann Testing Laboratories Lt. 5550 McAdam Road, Mississauga, Ontario L4Z 1P1 (416) 890-2555 (see Appendix B4.2)	methane, scan for volatile and extractable organic parameters on the U.S. E.P.A. priority pollutant list
3. Isotope Laboratory, Department of Earth Sciences University of Waterloo, Waterloo, Ontario N2L 3G1 (519) 885-1211, ext. 2580 (see Appendix B4.3)	oxygen-18, deuterium, direct counting of tritium, enriched counting of tritium, carbon-13, and some chloride analyses
4. Rosentiel School of Marine and Atmosphere Science, Tritium Laboratory, 4600 Rickenbacker Causeway, Miami, Florida 33149-1098 (305) 361-4100 (see Appendix B4.4)	enrichment and low level counting of tritium in ultra-low activity water
5. Isotrace Laboratory, University of Toronto, 60 St. George St., Toronto, Ontario M5G 1A7 (416) 978-2241 (see Appendix B4.5)	accelerator counting of carbon-14 activity

B3 QUALITY ASSURANCE/QUALITY CONTROL

As a means of assessing the accuracy of laboratory analyses and potential biases due to ground water sampling methods, a quality assurance/quality control (QA/QC) program was implemented in both the field and laboratory.

B3.1 FIELD QA/QC

B3.1.1 VARIABILITY DUE TO SAMPLING AND ANALYTICAL METHODOLOGIES

Select split and duplicate samples were submitted to the laboratories.

Split samples were collected by dividing the same sample between two bottles. These are used to assess the reproducibility of the analytical techniques. Split sample analysis results are listed with the chemistry data in Tables J1 to J3 in Appendix J. No split samples were collected for low-level tritium counting at the University of Miami.

Duplicate samples are a separate, second set of samples collected in the same manner as the first, at approximately the same time. These act as a check on the reproducibility of sampling methodologies. Duplicate sample analysis results are listed with the chemistry data in Tables J1 to J3 of Appendix J. No duplicates were collected for low-level tritium counting at the University of Miami.

Table B3-1 presents the approximate variations in each parameter based on the split and duplicate samples. Variations between the two types of samples have not been differentiated because the variations associated with split samples were

approximately the same as the variations associated with the duplicate samples. This implies that variability during any one sampling run due to sampling methods was minimal. Estimates of percent variation were not made where more than 50% of the duplicate and split sample pairs had one or more values below detection.

Table B3-1 indicates there was good reproducibility of results for most parameters, with the average percent variation generally being 5% or less. The parameters with greater than 10% average variation were iron (10%), dissolved inorganic carbon (15%) and dissolved organic carbon (23%).

For the stable isotopes oxygen-18 (^{18}O) and deuterium (^2H) it is most appropriate to present analytical/sampling variability as ± 8 ‰ values since the values are already expressed as ratios relative to SMOW. This is the difference (δ) in the isotopic ratios ($^{18}\text{O}/^{16}\text{O}$ and $^2\text{H}/^1\text{H}$) of the sample, in parts per thousand expressed as ‰ with respect to Standard Mean Ocean Water (SMOW). For both oxygen-18 and deuterium results were also available from laboratory duplicate analyses as well as from the field split and duplicate samples. The range in variability of the oxygen-18 results was ± 0.0 to ± 0.16 ‰, averaging ± 0.07 ‰. The range in variability of the deuterium results was ± 0.0 to 2.7 ‰, averaging ± 0.85 ‰.

For tritium, the variability between split and duplicate sampling was much less than the analytical error reported by the laboratory. The analytical error for direct counting ranged from ± 6 to 8 Tritium Units (T.U.). The analytical error for enriched counting ranged from ± 0.7 to 1.2 T.U. The analytical error for enriched counting of very low level activity water was ± 0.1 T.U.

TABLE B3-1: PERCENT VARIATION IN CHEMICAL RESULTS DUE TO ANALYTICAL AND SAMPLING METHODOLOGIES BASED ON SPLIT AND DUPLICATE SAMPLES

1. General Chemical Indicators

<u>Parameter</u>	<u>Average Variation(%)</u>	<u>Range of Variation (%)</u>	<u>Number of Samples</u>
● Alkalinity (as CaCO_3)	3	0-9	12
● Dissolved Inorganic Carbon	15	0-57	12
● Total Dissolved Solids	5	0-17	12

2. Major Cations

<u>Parameter</u>	<u>Average Variation(%)</u>	<u>Range of Variation(%)</u>	<u>Number of Samples</u>
● Calcium (Ca)	1	0-5	12
● Magnesium (Mg)	3	0.3-16	12
● Potassium (K)	5	0-20	12
● Sodium (Na)	2	0.1-14	12
● Strontium (Sr)	2	0-6	12
● Silicon (Si)	3	0.2-9	12

3. Major Anions

<u>Parameter</u>	<u>Average Variation(%)</u>	<u>Range of Variation(%)</u>	<u>Number of Samples</u>
● Bicarbonate (HCO_3)*	3	0-9	12
● Chloride (Cl)	2	0-4	12
● Fluoride (F)	3	0.7-9	12
● Sulphate (SO_4)	1	0-5	12

* Calculated from alkalinity

TABLE 3-1 (continued)

Minor Cations*

<u>Parameter</u>	<u>Average Variation(%)</u>	<u>Range of Variation(%)</u>	<u>Number of Samples</u>
• Aluminum (Al)	-75% of data pairs have one value below detection-		
• Barium (Ba)	6	5-11	6
• Beryllium (Be)	-83% of data pairs have one value below detection-		
• Boron (B)	2	0-6	12
• Cadmium (Cd)	-67% of data pairs have one value below detection-		
• Chromium (Cr)	9	0-73	8
• Cobalt (Co)	-all but one value below detection-		
• Copper (Cu)	-83% of data pairs have one value below detection-		
• Iron (Fe)	10	0-33	12
• Lead (Pb)	-all values below detection-		
• Manganese (Mn)	2	0-14	8
• Molybdenum (Mo)	-83% of data pairs have one value below detection-		
• Nickel (Ni)	3	0-9	7
• Phosphorus (P)	2	0-5	6
• Silver (Ag)	-92% of data pairs have one value below detection-		
• Thorium (Th)	-83% of data pairs have one value below detection-		
• Titanium (Ti)	-all values below detection-		
• Vanadium (V)	-75% of data pairs have one value below detection-		
• Zinc (Zn)	-75% of data pairs have one value below detection-		
• Zirconium (Zr)	-all values below detection-		

* variations only estimated for those parameters having $\geq 50\%$ of their data pairs with both values above detection

5. Minor Anions

<u>Parameter</u>	<u>Average Variation(%)</u>	<u>Range of Variation(%)</u>	<u>Number of Samples</u>
• Bromine (Br)	-all values below detection -		
• Nitrite (NO ₂)	-all values below detection -		
• Nitrate (NO ₃)	-all but one value below detection -		
• Phosphate (PO ₄)	-all values below detection-		
• Sulphide (S)	-75% of data pairs have one value below detection-		

6. Organic Constituents

<u>Parameter</u>	<u>Average Variation(%)</u>	<u>Range of Variation(%)</u>	<u>Number of Samples</u>
• Dissolved Organic Carbon	23	0-61	12
• Methane	7	0-31	15

B3.1.2 VARIABILITY IN DISSOLVED ORGANIC CARBON RESULTS

As indicated previous the dissolved organic carbon results exhibited the greatest variability between split and duplicate samples. There is also considerable variability between monitoring runs. For example, at monitor 85-1-11 the dissolved organic carbon concentration was reported as 62 mg/L for June 17, 1986 and 9.5 mg/L for August 26, 1986. The majority of dissolved organic carbon concentrations also appear to be elevated over the 10 mg/L or less normally observed in ground waters like those at the Preferred Site. The reason for the elevated and variable concentrations was not confirmed. Future analyses for dissolved organic carbon should carefully evaluate the analytical and field sampling errors and if required, employ alternative methodologies.

B3.1.3 VARIABILITY IN METHANE RESULTS

Methane results from the August 26, 1986 sampling were generally lower than other sampling periods. Consultation with the laboratory indicated that the samples had initially been equilibrated for only one hour, compared to the normal 24 hours. The results reported were re-run at 24 hours, but because of the lower values remain suspect.

Methane results from the deep overburden monitors with a diameter of 52 mm (85-8-8, 85-12-8), were much lower than those from monitors with a diameter of only 19 mm. (85-8-3, 85-12-3). Field testing (Table B3-2) confirmed that substantial losses of methane can occur by volatilization out of the larger diameter monitors. Consequently the higher concentrations observed in monitors 85-8-3 and 85-12-3 are considered to be most representative of actual values.

**TABLE B3-2: COMPARISON OF METHANE CONCENTRATIONS IN 52 mm
AND 19 mm MONITORS**

MONITOR #	85-8-3	85-8-8	85-12-3	85-12-8
Diameter (mm)	19	52	19	52
Depth of screen (m)	25.83 to 26.83	24.66 to 26.38	25.90 to 6.80	24.55 to 25.15
1/2 day after flushing	46.8	4.6	171.1	0.8
1/2 after flushing	61.1	0.9	161.1	0.7
1-1/2 days after flushing	105.6	6.8	249.0	0.5
2 days after flushing	98.9	1.6	230.9	2.4
3 days after flushing	99.9	0.9	258.3	7.8

All concentrations in ppm by volume

B3.2 LABORATORY QA/QC

The internal quality assurance/quality control procedures used by the various laboratories are described in this section.

This section is organized as follows.

B3.2.1 Analytical Methods and QA/QC Procedures
Barringer Magenta Limited

B3.2.2 Analytical Methods and QA/QC Procedures
Mann Testing Laboratories Limited

B3.2.3 Analytical Methods and QA/QC Procedures
Isotope Laboratory, University of Waterloo

B3.2.4 Analytical Methods and QA/QC Procedures
Tritium Laboratory, University of Miami

B3.2.5 Analytical Methods and QA/QC Procedures
Isotrace Laboratories, University of Toronto

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B3.2.1 ANALYTICAL METHODS AND QA/QC PROCEDURES

BARRINGER MAGENTA LTD.



ANALYTICAL PROTOCOLS USED IN
THE OWMC WATER QUALITY SURVEY

Prepared for:
Gartner-Lee & Associates
Toronto Buttonville Airport
Markham, Ontario
L3P 3J9

Prepared by:
Barringer Magenta Limited
304 Carlingview Drive
Rexdale, Ontario
M9W 5G2

September, 1986

1. INTRODUCTION

Barringer Magenta Limited is currently providing analytical services to Gartner-Lee & Associates with respect to a survey being performed for the Ontario Waste Management Corporation (OWMC). This document provides a brief description and summary of the analytical protocols used for the analyses of both inorganic and organic parameters for the above mentioned water quality survey.

This protocol is not designed to be a regurgitation of the analytical methods manual and, as a result, the analytical methods used are described in a very brief tabular form. In addition to the methodologies, the quality control and quality assurance protocols are also described. Once again, a general description is provided along with more detailed information as it pertains to this particular program. For the most part, the procedures used are taken from well documented sources and any in-house modifications are documented accordingly.

2. ANALYTICAL METHODOLOGIES

The analytical methods used for the water analyses provided to Gartner-Lee & Associates under this contract are summarized in Table 1. It should be noted that, for the most part, the methods are identical to those given in the listed references. If the size of sample aliquots taken or the proportions of reagents used were chosen in order to make the analyses more convenient based on the present facilities and capabilities of the laboratory then these were not considered to be major modifications to the method. In the cases where significant differences from the published methodologies are apparent, these have been noted accordingly.

Tables 2 through 4 give the detection levels that were reported for this program. In some cases, such as the ion chromatography and ICAP analyses, all of the parameters which are reportable as part of these packages have been listed. Since these services are offered as a package, results for all of the parameters are given at no additional charge.

TABLE 1

Summary of Analytical Methods

<u>Parameter</u>	<u>Reference</u> ^{1.}	<u>Modified ?</u> ^{2.}	<u>Description</u>
pH	SM-423 MOE-PC1 EPAL-150.1	No	- electrode - purchased buffer stds
Alkalinity	SM-403 MOE-AB1 EPAL-310.1		- fixed endpoint titration - to pH 4.5 - standardized H ₂ SO ₄ (0.002-0.01 N depending upon levels expected) - standardization using NaOH and KHC ₈ H ₄ O ₄
T.D.S.	SM-209B MOE-SD.1 EPAL-160.1	Yes	- filtration through 0.45 um membrane filter - dried at 105°C - gravimetric determination of residue
Cations	SM-305 MOE-MD54 EPAL-200.7	No	- A.R.L. Model QA-137 Inductively Coupled Argon Plasma Emission Spectrophotometer - calibration standards prepared from purchased solutions - computerized correction for spectral interferences
Anions	SM-429 MOE-CD18, NB1, SH12 EPAL-300.0	No	- Dionex Model 2110i Ion Chromatograph - Eluent: 0.0024 M Na ₂ CO ₃ 0.003 M NaHCO ₃ - Columns: AS4A + A64 (guard column) - Detector: conductivity - Standards: prepared from salts
D.O.C./D.I.C.	Manufacturers Literature SM-505 MOE-CB20 EPAL-415.1	No	- subcontracted to Beak Consultants Ltd. - infra-red detection - Beckman system

TABLE 1 (Continued)

Summary of Analytical Methods

<u>Parameter</u>	<u>Reference</u> ^{1.}	<u>Modified ?</u> ^{2.}	<u>Description</u>
Sulphide	SM-427C MOE-SI18 EPA1-376.2	No	- Colourimetry with ferric chloride and dimethyl-p-phenylenediamine (methylene blue method) - standards from Na ₂ S, standardized by iodometric titration

1. SM = Standard Methods for the Examination of Water and Wastewater (16th Ed.), APHA-AWWA-WPCF (1985).

MOE = Handbook of Analytical Methods, Ontario Ministry of the Environment (1983).

EPA1 = Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency (revised 1983)

EPA2 = Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Final Rule and Interim Final Rule and Proposed Rule, Federal Register: Environmental Protection Agency, 40 CFR Part 136 (1984).

2. The methods used are similar to those listed in the references with the possible exception of the volumes taken or reagent proportions used. If significant deviations from the published methods are used, this is indicated here and the modification is flagged (*) in the "Description" column.

TABLE 2

Analytical Detection Limits

(mg/l unless otherwise noted)

pH	± 0.01 pH units
Alkalinity	0.2 mg CaCO_3 /l
Total Dissolved Solids	1.0 mg/l
Cations	(see Table 3)
Anions	(see Table 4)
D.O.C./D.I.C.	0.5 mg/l
$\text{S}^{=}$	0.001

TABLE 3

I.C.A.P. Multi-element Package Detection Limits (mg/l)

Ag	0.005	Cu	0.01	Pb	0.05
Al	0.05	Fe	0.01	Si	0.05
B	0.005	K	1.0	Sr	0.001
Ba	0.005	Mg	0.01	Th	0.05
Be	0.0005	Mn	0.01	Ti	0.005
Ca	0.05	Mo	0.2	V	0.005
Cd	0.01	Na	1.0	Sn	0.05
Co	0.05	Ni	0.05	Zr	0.02
Cr	0.01	P	0.5		

TABLE 4

Ion Chromatography Package Detection Limits (mg/l)

F ⁻	0.005
Cl ⁻	0.01
NO ₂ ⁻	0.02
PO ₄ ⁼	0.1
Br ⁻	0.05
NO ₃ ⁻	0.05
SO ₄ ⁼	0.05

3. QUALITY ASSURANCE AND QUALITY CONTROL

In any analytical program it is vital that proper quality assurance and quality control practices be followed in order to establish credibility in the final results obtained. These practices must include both good technique and implementation as well as thorough documentation of the procedures employed. A generalized summary of the QA/QC procedures routinely employed at Barringer are presented in Appendix I. This excerpt was taken from a Manual of Standard Operating Procedures for the laboratory operations at Barringer.

In programs involving water quality analyses, the inclusion of blanks and sample replicates is a fairly easy procedure. The inclusion of reference standards, however, becomes a somewhat more difficult issue. Up until recently, the onus was on the laboratory to prepare standard solutions which could be used for this purpose, the only criteria being that their source was independent from the standards used for calibration purposes. In this way it was hoped that an independent mechanism would exist for verifying the accuracy of the calibration standards and as a monitor on recovery of various extraction processes. More recently, however, various organizations have been producing concentrates which are meant to be used for quality control and water analysis programs. These include the National Bureau of Standards, the U.S. Environmental Protection Agency and Environmental Resources Associates. Barringer has been employing the standard provided by the U.S. E.P.A. for many of its water quality tests. A list of the standards used in this program is presented in Table 5.

Control charting is a regular quality control procedure at Barringer. Control charts are established to monitor overall precision and accuracy of the analytical techniques used. In

TABLE 5

Reference Standards Used in O.W.M.C. Survey

<u>Standard</u>	<u>Certified Parameters</u>
EPA - Minerals	pH, Alkalinity, F^- , Cl^- , $SO_4^{=}$, Conductance, TOS
EPA - Nutrients	NH_3-N , TKN, Total P, NO_3^- , PO_4^{-3}
EPA - Trace Metals - I	ICAP, AA, As, Hg

order to simplify any subsequent presentation requirements it was decided that control charts be set-up specifically for this program and kept separate from the normal lab control charts. In this way the specific program can be monitored and not lost in the routine analytical work performed by the laboratory. Samples of these control charts have been presented along with the quality assurance description in Appendix I.

4. REFERENCES

More detailed information on the procedures outlined in this manual can be found in the following references.

A. Quality Control References

1. United States Environmental Protection Agency, HANDBOOK FOR ANALYTICAL QUALITY CONTROL IN WATER AND WASTEWATER LABORATORIES, Ref. EPA-600/4-79-019 (March 1979)
2. Ontario Ministry of the Environment, THE WATER QUALITY LABORATORIES, DATA QUALITY SUMMARY, D.E. King and P. Fellin (1975)
3. Ontario Ministry of the Environment, QUALITY CONTROL AND DATA EVALUATION PROCEDURES, D.E. King (1976)
4. Ontario Ministry of the Environment, PRINCIPLES OF CONTROL CHARTING, D.E. King (1984)

B. Analytical Methods Manuals

1. U.S. Environmental Protection Agency, METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES, EPA Ref. 600/4-79-020 (May 1979)
2. Environment Canada, ANALYTICAL METHODS MANUAL (1979), Inland Waters Directorate, Water Quality Branch, Ottawa, Ontario (Aug. 1979)

3. Ontario Ministry of the Environment, HANDBOOK OF ANALYTICAL METHODS FOR ENVIRONMENTAL SAMPLES, Laboratory Services and Applied Research Branch, Rexdale, Ontario (December 1983)
4. A.P.H.A., A.W.W.A., W.P.C.F., STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER, 16th Ed., (1985)
5. U.S. Environmental Protection Agency, METHODS FOR ORGANIC CHEMICAL ANALYSIS OF MUNICIPAL AND INDUSTRIAL WASTEWATER, Ref. EPA-600/4-82-057 (July 1982)
6. U.S. Environmental Protection Agency, MANUAL OF CHEMICAL METHODS FOR PESTICIDES AND DEVICES, A.O.A.C., Ref. ISBN 0-935584-23-4 (July 1976)
7. American Society for Testing and Materials, ANNUAL BOOK OF A.S.T.M. STANDARDS, PART 31, WATERS (1979)
8. American Society for Testing and Materials, ANNUAL BOOK OF A.S.T.M. STANDARDS, Vol. 4.08, SOIL AND ROCKS: BUILDING STONES (1984)
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10. Rudolf Bock, A HANDBOOK OF DECOMPOSITION METHODS IN ANALYTICAL CHEMISTRY, Halsted Press (1979)
11. A.O.A.C., OFFICIAL METHODS OF ANALYSIS OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS (1975)

APPENDIX I

Quality Assurance/Quality Control

QUALITY ASSURANCE AND QUALITY CONTROL PRACTICES

GENERAL CONCEPTS

The purpose of a QA/QC program is to ensure consistency of data quality and accuracy in the analytical results. It must provide a routine method of monitoring the analytical process and provide a quick feedback to the analyst as to the degree of control. The then main determinants of control are background levels, precision and accuracy. These are monitored routinely by the insertion into the analytical scheme of blanks, replicates and reference standards, respectively.

With the monitoring of these three facets of the analytical process, documentation is also essential to provide a time-based monitor of the quality of the various analytical methods. This can be accomplished by centralized recording of the data obtained, and by the use of control charts. These would provide a realistic summary of analytical performance over time, enabling accurate determination of confidence and control limits. If these limits prove to be wider than is considered acceptable, it provides feedback on methods which are in need of re-evaluation and modification. It is essential that everyone involved in analytical work be aware of the importance of QA/QC protocols and adhere strictly to the accepted procedures.

BACKGROUND MONITORING

During an analytical process, backgrounds can be introduced via a number of different processes. If glassware has not been cleaned properly, contamination may be introduced from these sources. This contamination would be inconsistent and

sporadic. Another source of contamination could be from the reagents used in the analytical process. Backgrounds due to reagent contaminants would be much more consistent, showing up as a constant background in all samples.

In order to determine whether one of the former situations exist, reagent blanks are inserted in each work order at a frequency of one reagent blank for every 30 samples analyzed. It should be noted that this is not simply a calibration blank but a sample which is taken through every digestion, extraction or colour development phase of the analytical method. The only thing omitted is the sample aliquot. Reagent contaminations are easily discovered by analysis of these blanks, especially if a number of them have been included in a work order. An example is the blank observed when a poor grade of potassium permanganate is used for digestions of sediments and sludges for mercury analysis. Analysis of several blanks would give a constant background reading with a very tight precision. This may represent a mercuric impurity in the reagent and should be corrected for as long as the precision is very close and the sample levels are significantly higher (at least 5x).

If some blanks give large readings and others give none, a sporadic contamination has probably occurred. This type of contamination cannot be corrected for and the analysis of that batch of samples should be terminated, the glassware rewashed and the entire analysis repeated.

MONITORING OF ANALYTICAL PRECISION

Analytical precision is simply the reproduceability of the procedure being followed. The usual method of monitoring this precision is the analysis of some samples in duplicate. This is done at a frequency of one replicate for every 30 samples

analyzed. The sample repeated is usually the one immediately following the previous blank. For example, if sample #10 was a blank, sample #20 would be a repeat of sample #11. As in the case of the reagent blank analyses, this is not simply a re-analysis of the same sample solution but involves taking a separate sample aliquot and putting it through the entire analytical process. One point to note is that poor precision observed by this process is not necessarily just an indication of a poor analysis approach. Poor precision can also occur if an inhomogenous sample is involved. In this case, the analytical precision may be excellent but, in effect, the sample aliquots being taken for analysis are not identical. This can sometimes be discerned for large work orders if the precision for a number of analyses of a reference standard show markedly better precision than that observed in the sample replicates. If this is suspected, the only recourse is to re-prepare the sample by homogenization, if feasible, and re-analyze it.

MONITORING ACCURACY

In order to measure the degree of accuracy in any analytical method several factors must be taken into account. The calibration standards used must be properly prepared, the analytical procedure must not cause any loss of analyte, interferences must be properly eliminated or accounted for and analyte recoveries must be quantitative.

To monitor calibration standard accuracy, it is necessary to have an independent lab control solution that has sufficient stability to be used over a period of time. All calibration standards should be prepared from primary standard grade reagents but the preparation process must be constantly

monitored. The first step to be taken when a new series of standard solutions is prepared is to compare the new standards to the old ones. If a discrepancy occurs, the old standards may be the problem. Subsequent to this comparison, therefore, a reference standard solution should be analyzed against the new standards and the value obtained compared to the certified or accepted value. If the value obtained does not lie within a given acceptance window, usually less than a 5% deviation from the certified value, the standards should be re-prepared. Purchased standards, such as those available for GC/MS priority pollutant work, should also be evaluated by a similar procedure before their implementation for calibration purposes.

To measure losses of analyte as a result of the analytical process, reference standards are inserted at a frequency of one standard for every 30 samples analyzed. This is inserted in every thirtieth sample position. The reference standards should be chosen so as to match the sample matrix as closely as possible, and to have an analyte level close to that expected for the samples. If the results obtained are not within the specific acceptance windows (see Section 4.5), the procedure should be reviewed, the problem corrected and the sample re-analyzed.

New reference materials are constantly being introduced as supplies of the older one are depleted. Some of the standards to be used for our routine analyses are given in Table 4.

Interferences could also be monitored in a similar manner by analyzing either synthetic or purchased interference check samples. This type of standard is especially useful for I.C.A.P. analysis where corrections for spectral interferences are performed as a routine part of the analytical process. These standards usually contain low levels of analytes with fairly substantial excesses of known interferents.

CONTROL CHARTS

Control charts are used to monitor the long-term data quality for analysis of reference standards to enable a quick visual assessment of the degree of control for a particular analytical run. They are basically a plot of analyte recovery as a function of time. Whenever a given standard is analyzed with a work order, its result is plotted on the appropriate control chart. Over a period of time, the analytical precision can be viewed directly on the chart. Control limits can be set up and acceptance criteria established. An example of a typical control chart is given in Figure 7. If the result obtained for a given standard run lies outside the given control limits, the sequence of samples associated with that standard run must immediately be scheduled for re-analysis.

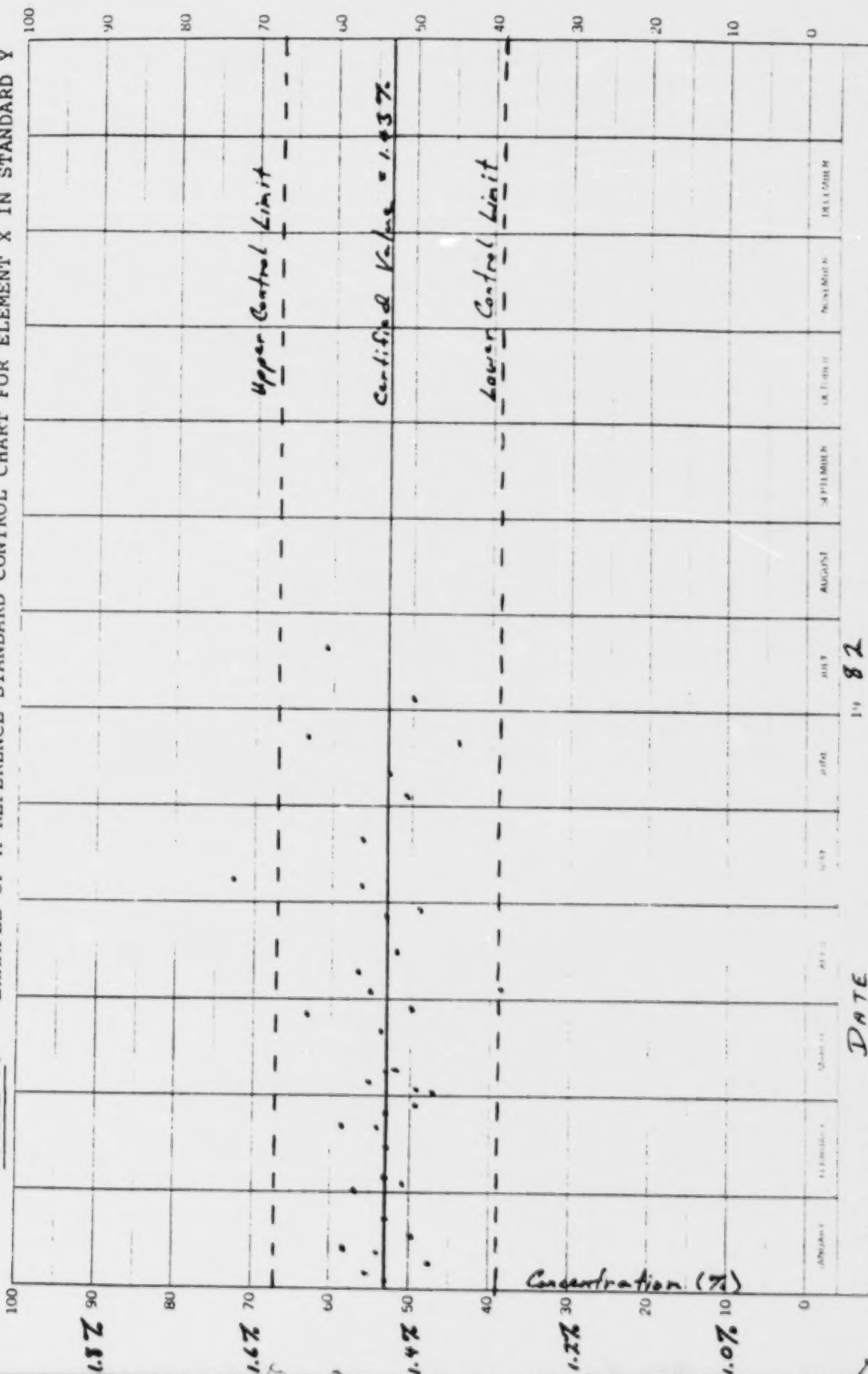
Each lab supervisor should keep a binder with all of the control charts for all standards used routinely and it should be kept as a integral part of the QA/QC process. Quality control is a vital part of the laboratory operation and the practices described here should be adhered to strictly in order to ensure the client of accurate data and to keep the laboratory's reputation held in high regard.

TABLE 4

REFERENCE STANDARDS MOST COMMONLY USED

<u>Matrix</u>	<u>Standard (Source)</u>
Rock Analysis:	SY-2 (Canmet) SY-3 (Canmet) MRG-1 (Canmet)
Soil/Sediment Analysis:	Estuarian Sediment (SRM 1646-NBS) River Sidemtn (SRM 1645-NBS) SO-1 to SO-4 (Canmet) GXR-1 to GXR-6 (U.S.G.S.) Deer Lake #1, 2 (in-house)
Vegetation Analysis:	Citrus Leaves (SRM 1572-NBS) Pine Needles (SRM 1575-NBS) Orchard Leaves (SRM 1571-NBS) Tomato Leaves (SRM 1573-NBS)
Tissue Analysis:	Bovine Liver (SRM 1577a-NBS) Oyster Tissue (SRM 1566-NBS)
Water Analysis:	WASTEWATR Set (E.R.A.) TRACE ELEMENTS IN WATER (SRM 1643a-NBS) Purchased Metals Stock Solutions (Canlab, BDH, etc.)
Miscellaneous:	TRACE ELEMENTS IN COAL-BITUMINOUS (SRM 1632a-NBS) TRACE ELEMENTS IN COAL-SUBBITUMINOUS (SRM 1635-NBS) TRACE ELEMENTS IN COAL FLY ASH (SRM 1633a-NBS) STAINLESS STEEL (SRM 101f-NBS)

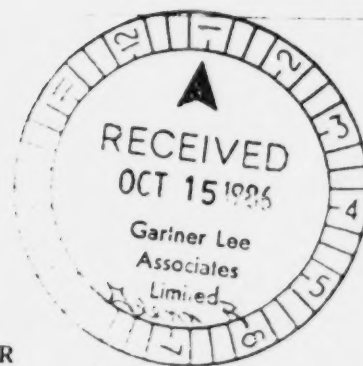
FIGURE 7: EXAMPLE OF A REFERENCE STANDARD CONTROL CHART FOR ELEMENT X IN STANDARD Y



B-71

B3.2.2 ANALYTICAL METHODS AND QA/QC PROCEDURES

MANN TESTING LABORATORIES LTD.



METHANE ANALYSIS IN WATER
(Using Headspace Technique)

The samples were prepared by first removing ten (10) ml of water and replacing this volume with a like amount of pure nitrogen. The samples were then allowed to stand at room temperature (20°C) for 24 hours to permit equilibrium to occur.

The analysis involved injecting 0.5uL of the headspace into a Hewlett Packard 5840A Gas Chromatograph equipped with a Flame Ionization Detector (FID). The parameters of the GC were as follows:

Detector Temp.	250°C
Oven Temp.	100°C
Injector Temp.	100°C
Column	7 ft. Poropak T
Injection Vol.	0.5uL

VOLATILE ANALYSIS - WATER SAMPLES

Sampling Preparation - Collection and Handling

Water samples for purgeable organics were collected in 50 ml capacity amber glass bottles equipped with Tuf-Bond discs and screw caps with a syringe access hole in the centre. The bottles had been previously cleaned and heated at 200°C for at least 4 hours, purged with nitrogen and sealed with PTFE coated silicone and open top caps prior to transportation to the sampling sites.

The bottles were filled to slight overflow, then sealed so that no air bubble was present in the sample. They were immediately returned to Mann Testing Labs and stored at 4°C until analysed.

Preparation of Standard Solutions

Stock standard solutions were prepared by injecting appropriate amounts of each pollutant into 25 ml of glass distilled methanol (Burdick and Jackson) in reactiflasks fitted with Minnert valves (Chromatographic Specialties Ltd.) which provide complete protection and easy access via a hypodermic needle. The resulting concentration of 1 mg/ml was further diluted to give methanolic solutions of 400 ug/ml, 40 ug/ml and 4 ug/ml for each component. Gaseous standards were prepared in a similar manner by injecting the gaseous compound from a 10 ml gas tight syringe into a pre-weighed reactiflask filled with 25 ml of methanol. The syringe needle was slightly above the ethanol meniscus while injecting, hence enabling the gas to dissolve rapidly into the methanol. The flask was re-weighed again to determine the amount

in the solution.

Aqueous composite standards were prepared by injecting appropriate aliquots of methanolic standard in 250 ml sample bottles filled with purified water.

The relative retention times (RRT) were compared to that of the internal standard, deuterated chlorobenzene (RRT = 1.00) which eluted close to the middle of the chromatogram. Detection limits were determined by purging aqueous composite standard mixture at various concentrations.

Instrumentation

Analysis of volatile organics in water was conducted using a UNACON 780B automatic concentrator (Envirochem Inc., Kemblesville, P.A.). This instrument utilized the technique developed by Bellar and Lichtenberg for the isolation and concentration of volatiles for chromatographic analysis. In general, this process involved gas stripping of the sample and adsorption of the organic compounds on a sorbent trap followed by thermal desorption and analysis by gas chromatography or gas chromatography/mass spectrometry.

The sample purging assembly included a sparger vial with a side port which was equipped with an open top screw cap and Tuf-Bond septum. A 30 ml vial was used to obtain detection limits as reported. Sample was transferred to the vial through a transfer line by pressurizing the sample bottle which was inverted and clamped on the side of the instrument. The transfer line was constructed of 1/16" teflon tubing with two Luer Lock

connectors at each end. Two 17-gauge needles were used to puncture the septa of both the bottle and the side port.

Prior to the start of the analysis, the sparger vial was purged with helium for 5 minutes by rotating the valve to "Trap-Out" mode. In this position, any contaminants that were present in the sparger vial were purged out of the system without entering the trap. An appropriate aliquot of the water was then transferred to the sparger and purged for 15 minutes at the "Trap-In" mode. The trap was heat desorbed and the organics backflushed into the second trap. When this transfer process was completed, the second trap was again heated, releasing all adsorbed organics into the capillary GC/MS system for identification and quantification.

The MDL (Method Detection Limit) listed in the volatile section is the limit that the compound can be identified and quantified in the sample matrix using the purge & trap GC/MS method.

QA/QC

Prior to sample analysis reference standards were analyzed to determine the instrument response for standards of known levels. Instrument blanks were then analyzed to determine the extent of any instrument contamination. Travelling blanks for each set of samples were analyzed to measure any possible background contamination caused by the sample container. At ten sample intervals duplicate samples were analyzed to monitor the analytical reproducibility.

TABLE I
RETENTION DATA, % RECOVERY & CHARACTERISTIC
IONS OF THE VOLATILE ORGANICS

<u>Compound</u>	<u>RRT</u>	<u>% RECOVERY</u>	<u>PRIMARY ION (m/e)</u>	<u>SECONDARY IONS (m/e)</u>
Dichlorodifluoromethane	0.477	99.8	85	87
Chloromethane	0.486	100.3	50	52
Vinyl Chloride	0.495	106.2	62	64
Bromomethane	0.511	105.0	94	96
Chloroethane	0.516	91.9	64	96
Trichlorofluoromethane	0.545	101.6	101	103
1,1-Dichloroethylene	0.568	98.6	61	63,96
Dichloromethane	0.571	92.7	49	84
t-1,2-Dichloroethylene	0.608	92.3	61	63,96
1,1-Dichloroethane	0.614	97.2	63	65,83
Chloroform	0.661	90.5	83	85,87
1,2-Dichloroethane	0.690	80.3	62	64,98
1,1,1-Trichloroethane	0.707	102.5	97	61,99
Benzene	0.729	97.5	78	51,77
Carbon Tetrachloride	0.737	97.6	117	119,121
1,2-Dichloropropane	0.769	91.2	63	62,76
Bromodichloromethane	0.779	94.2	83	82,129
Trichloroethylene	0.782	101.2	95	130
1,3-Dichloropropene(Z)	0.827	90.8	75	110
1,3-Dichloropropene(E)	0.857	78.9	75	110
1,1,2-Trichloroethane	0.866	71.1	83	97
Toluene	0.888	91.4	91	92
Dibromochloromethane	0.914	79.7	129	127
Tetrachloroethylene	0.960	126.2	129	166,131
Chlorobenzene	1.003	92.7	112	77,114
Ethyl Benzene	1.026	93.9	91	106
m,p-Xylenes	1.038	95.4	91	105,106
Bromoform	1.042	52.5	173	171,175
o-Xylene	1.067	88.3	91	105,106
1,1,2,2-Tetrachloroethane	1.066	45.0	83	85
1,3-Dichlorobenzene	1.199	86.4	146	148,111
1,4-Dichlorobenzene	1.204	86.7	146	148,111
1,2-Dichlorobenzene	1.231	85.4	146	148,111
Acrolein	0.528	22.1	56	55
Acrylonitrile	0.551	7.9	53	52
Pentane	0.512	82.7	43	42,57
Dimethyl Sulphide	0.518	80.2	47	62,45
Methylethylketone	0.591	8.8	43	72
Hexane	0.622	84.3	57	41,43
Heptane	0.787	97.8	43	57,71
4-Methyl-2-pentanone	0.823	26.6	43	58,85

TABLE I(cont'd)

REPRODUCIBILITY OF SELECTED VOLATILE
ORGANICS USING PURGE & TRAP SYSTEM

Compound	Ion (m/e)	Peak Intensity			SDV	% C.V.
		Run#1	Run#2	Run#3		
Dichlorodifluoromethane	85	41408	46016	47488	3171.9	7.1
Chloromethane	50	19840	18560	19072	644.3	3.4
Vinyl Chloride	62	81664	83072	89728	4307.2	5.1
Bromomethane	94	49536	52608	66048	8781.8	15.7
Chloroethane	64	39872	35648	47616	6069.7	14.8
Trichlorofluoromethane	101	100992	93568	123008	15310.9	14.5
1,1-Dichloroethylene	61	22848	21600	20832	1017.5	4.7
Dichloromethane	84	24096	20512	20896	1967.8	9.0
t-1,2-Dichloroethylene	61	32032	28064	27776	2378.4	8.1
1,1-Dichloroethane	63	54272	48064	50496	3128.2	6.1
Chloroform	83	55168	52160	46528	4385.9	8.6
1,2-Dichloroethane	62	31904	31296	35840	2467.8	7.5
1,1,1-Trichloroethane	97	48256	50432	51008	1451.5	2.9
Benzene	78	99200	93184	105984	6403.8	6.4
Carbon Tetrachloride	117	37824	37248	40896	1961.2	5.1
1,2-Dichloropropane	63	21984	20768	24064	1666.8	7.5
Bromodichloromethane	83	48640	51136	51136	1441.1	2.9
Trichloroethylene	130	46208	43072	46208	1810.6	4.0
1,3-Dichloropropene(Z)	75	38272	38848	40320	1056.2	2.7
1,3-Dichloropropene(E)	75	28704	25696	30400	2382.3	8.4
1,1,2-Trichloroethane	97	36672	32416	38848	3271.6	9.1
Toluene	91	145408	140544	145664	2885.0	2.0
Dibromochloromethane	129	47808	43200	52096	4449.0	9.3
Tetrachloroethylene	129	66176	64448	66816	1224.9	1.9
Chlorobenzene	112	104960	101248	96640	4168.0	4.1
Ethyl Benzene	91	139008	124032	135168	7778.6	5.9
m,p-Xylenes	91	111104	99584	117120	8910.8	8.2
Bromoform	173	34240	30336	30528	2200.6	6.9
o-Xylene	91	121856	113152	124032	5757.2	4.8
1,1,2,2-Tetrachloroethane	83	37312	33984	31072	3122.3	9.2
1,3-Dichlorobenzene	146	99584	88192	101504	7195.8	7.5
1,4-Dichlorobenzene	146	114304	101248	118400	8957.6	8.0
1,2-Dichlorobenzene	146	94976	86144	94464	4958.0	5.4
Acrolein	56	3452	2636	2872	419.9	14.1
Acrylonitrile	53	6024	4592	4984	740.0	14.2
Pentane	43	82048	71808	71296	6065.3	8.1
Dimethyl Sulphide	62	64384	56896	60544	3744.4	6.2
Methylethylketone	43	17024	23136	20757	3080.9	15.2
Hexane	57	66944	73472	84608	8931.6	11.9
Heptane	43	117248	123648	125824	4458.0	3.6
4-Methyl-2-pentanone	43	53440	64448	51904	6842.1	12.1

TABLE I (cont'd)

GC/MS
% RECOVERY REPRODUCIBILITY
5 ppb level

	% Recovery Run #1	% Recovery Run #2	% Recovery Run #3	Ave. % Recovery	SDV
Dichlorodifluoromethane	93.6	101.6	104.1	99.8	5.5
Chloromethane	88.7	99.1	113.2	100.3	12.3
Vinyl Chloride	92.1	112.1	114.4	106.2	12.3
Bromomethane	95.4	108.6	111.0	105.0	8.4
Chloroethane	93.8	91.9	90.0	91.9	1.9
Trichlorofluoromethane	105.6	95.8	103.3	101.6	5.1
1,1-Dichloroethylene	97.1	99.1	99.7	98.6	1.4
Dichloromethane	96.2	93.1	88.7	92.7	3.8
t-1,2-Dichloroethylene	88.1	91.8	96.9	92.3	4.4
1,1-Dichloroethane	93.2	103.1	95.4	97.2	5.2
Chloroform	97.4	92.1	82.1	90.5	7.8
1,2-Dichloroethane	75.0	73.5	92.5	80.3	10.6
1,1,1-Trichloroethane	100.8	101.5	105.3	102.5	2.4
Benzene	96.3	101.2	95.0	97.5	3.3
Carbon Tetrachloride	95.5	94.0	103.2	97.6	4.9
1,2-Dichloropropane	90.0	85.1	98.6	91.2	6.0
Bromodichloromethane	99.0	92.0	91.6	94.2	4.2
Trichloroethylene	103.9	97.5	102.1	101.2	3.3
1,3-Dichloropropene(Z)	87.3	88.6	96.4	90.8	4.9
1,3-Dichloropropene(E)	81.4	72.9	82.5	78.9	5.3
1,1,2-Trichloroethane	73.7	65.1	74.6	71.1	5.2
Toluene	93.7	90.6	89.9	91.4	2.0
Dibromochloromethane	81.2	73.3	84.7	79.7	5.0
Tetrachloroethylene	127.3	125.2	126.1	126.2	1.1
Chlorobenzene	96.4	92.9	88.7	92.7	3.9
Ethyl Benzene	95.8	92.5	93.5	93.9	1.7
m,p-Xylenes	98.1	91.5	96.6	95.4	3.5
Bromoform	56.7	50.2	50.5	52.5	3.7
o-Xylene	90.5	89.7	84.7	88.3	3.1
1,1,2,2-Tetrachloroethane	46.6	42.5	46.0	45.0	2.2
1,3-Dichlorobenzene	86.4	88.4	84.3	86.4	2.1
1,4-Dichlorobenzene	86.5	88.4	85.3	86.7	1.6
1,2-Dichlorobenzene	88.8	82.6	84.7	85.4	3.2
Acrolein	24.6	19.9	21.7	22.1	2.4
Acrylonitrile	9.2	7.0	7.6	7.9	1.1
Pentane	86.1	78.8	83.2	82.7	3.7
Dimethyl Sulphide	79.3	78.9	82.4	80.2	1.9
Methylethylketone	8.5	10.9	6.9	8.8	2.0
Hexane	85.9	81.8	85.2	84.3	2.2
Heptane	99.6	95.9	97.8	97.8	1.9
4-Methyl-2-pentanone	25.4	27.8	26.6	26.6	1.2

TABLE I (cont'd)

RETENTION TIME REPRODUCIBILITY

	Run #1 RRT	Run #2 RRT	Run #3 RRT	Ave. RRT	+ Limits For RRT
Dichlorodifluoromethane	0.488	0.473	0.471	0.477	0.012
Chloromethane	0.496	0.482	0.480	0.486	0.012
Vinyl Chloride	0.506	0.491	0.487	0.495	0.012
Bromomethane	0.520	0.507	0.505	0.511	0.010
Chloroethane	0.524	0.513	0.511	0.516	0.010
Trichlorofluoromethane	0.549	0.544	0.542	0.545	0.005
1,1-Dichloroethylene	0.571	0.568	0.565	0.568	0.005
Dichloromethane	0.575	0.570	0.569	0.571	0.005
t-1,2-Dichloroethylene	0.609	0.608	0.607	0.608	0.002
1,1-Dichloroethane	0.614	0.614	0.613	0.614	0.002
Chloroform	0.660	0.662	0.660	0.661	0.002
1,2-Dichloroethane	0.694	0.682	0.693	0.690	0.009
1,1,1-Trichloroethane	0.708	0.710	0.704	0.707	0.004
Benzene	0.731	0.733	0.723	0.729	0.008
Carbon Tetrachloride	0.739	0.741	0.731	0.737	0.005
1,2-Dichloropropane	0.773	0.774	0.760	0.769	0.010
Bromodichloromethane	0.783	0.784	0.770	0.779	0.010
Trichloroethylene	0.786	0.787	0.772	0.782	0.010
1,3-Dichloropropene (Z)	0.832	0.833	0.817	0.827	0.010
1,3-Dichloropropene (E)	0.862	0.863	0.846	0.857	0.012
1,1,2-Trichloroethane	0.873	0.873	0.851	0.866	0.012
Toluene	0.892	0.892	0.881	0.888	0.005
Dibromochloromethane	0.915	0.916	0.910	0.914	0.005
Tetrachloroethylene	0.960	0.960	0.959	0.960	0.002
Chlorobenzene	1.003	1.003	1.002	1.003	0.002
Ethyl Benzene	1.027	1.026	1.026	1.026	0.002
m,p-Xylenes	1.038	1.038	1.037	1.038	0.002
Bromoform	1.042	1.042	1.041	1.042	0.002
o-Xylene	1.066	1.068	1.068	1.067	0.002
1,1,2,2-Tetrachloroethane	1.066	1.066	1.066	1.066	0.001
1,3-Dichlorobenzene	1.201	1.200	1.197	1.199	0.003
1,4-Dichlorobenzene	1.206	1.205	1.202	1.204	0.003
1,2-Dichlorobenzene	1.232	1.232	1.229	1.231	0.003
Acrolein	0.534	0.525	0.524	0.528	0.007
Acrylonitrile	0.555	0.550	0.548	0.551	0.005
Pentane	0.507	0.519	0.511	0.512	0.008
Dimethyl Sulphide	0.512	0.526	0.517	0.518	0.009
Methylethylketone	0.585	0.597	0.592	0.591	0.007
Hexane	0.617	0.626	0.623	0.622	0.006
Heptane	0.784	0.790	0.787	0.787	0.004
4-Methyl-2-pentanone	0.821	0.826	0.823	0.823	0.004

EXTRACTABLE (EPA) ANALYSIS - WATER SAMPLES

Standard Compound Characterization

A Standard solution containing approximately 1.0 ng/ul of each of the selected priority pollutants was prepared and analysed by GC/MS to determine each compound's fragmentation pattern, relative retention time (RRT) and relative response factor (RRF) compared to the internal standard D₁₀ Phenanthrene. A 10 ppb dilution of this standard was routinely run prior to sample analysis to insure optimum performance of the GC/MS system. The minimum detection limit (MDL) represents the minimum level at which a compound can be detected and quantitated. Values were determined by comparison of the response of the labelled internal standards to the level of background interference in the region of the corresponding natural compound. These values are averages obtained from actual sample matrices.

Target Compound % Recovery

The % recovery of individual target compounds was determined by spiking 1 litre of purified distilled water at the 20 ppb level with a standard mixture containing all of the compounds of interest.

Recovery values and the method detection limit (MDL) are listed in Table II.

Sample Extractions

To monitor the extraction efficiency of individual sample extractions. Each sample was spiked at the 10 ppb level with a mixture of 11 deuterated acid extractables and 19 deuterated B/N compounds.

To monitor the injection efficiency all extracts were spiked with 10 ppb of D-10 Phenanthrene immediately prior to GC/MS analysis.

QA/QC Protocol

a) The use of a stock mixture of deuterated internal standards (Table III) to monitor extraction efficiency assures a high confidence level in the results of all sample extractions.

b) Travelling blanks were analysed at 10 sample intervals to insure that outside contamination was not interfering with the observed results.

c) Prior to sample analysis, reference standards at the 10 ppb level were analysed to demonstrate that the instrument was capable of the required sensitivity. Solvent blanks were run between standards and samples to monitor any possible cross contamination. Reference standards at various levels were analysed after every tenth sample.

Target Compound Identification and Quantitation

The GC/MS data files were searched for the selected pollutants using a computer program that searched successive regions of the chromatogram plotting out ion intensities of the two most abundant ions of both the target compound and labelled standards eluting in that region. The identity of detected compounds was verified by manual confirmation (mass spectra matching).

Quantitation of target compounds was achieved by comparing the peak heights of the natural compound to that of its analogous labelled standard which had been spiked into the sample at a known level. For those target compounds whose corresponding labelled standard was not available, the labelled standard that eluted closest to it was used for quantitation.

Additional Compound Identification

Additional compounds (non-targetted) present in the sample were tentatively identified by means of a computer generated mass spectra library search program. The mass spectra of the natural compound is compared to entries in the National Bureau of Standards (NBS) library containing approximately 35,000 compounds. The compounds reported as additional compounds were present in concentrations greater than 1 ppb (based on a 1:1 response to the internal standard, D₁₀-Phenanthrene) and had purity match values of greater than 800 (1000 = exact match).

TABLE II

EPA PRIORITY POLLUTANTS
MINIMUM DETECTION LIMITS & PERCENT RECOVERIES
(1 L water/20 ppb)

<u>ACIDIC COMPOUNDS</u>	<u>MWT</u>	<u>QUANT</u>			<u>%</u>
		<u>ION</u>	<u>RRT</u>	<u>MDL</u>	<u>REC</u>
Phenol	94	94	0.270	1.6	25.0
2-Chlorophenol	142	142	0.390	3.0	40.6
2,4-Dimethyl phenol	136	107	0.431	2.5	24.5
p-Chloro-m-cresol	156	156	0.485	2.0	83.4
2,4-Dichlorophenol	176	176	0.559	2.9	47.9
2,4,6-Trichlorophenol	210	195	0.609	3.3	70.3
2-Nitrophenol	153	153	0.609	2.0	29.6
2,4-Dinitrophenol	198	91	0.772	5.0	16.5
4,6-Dinitro-o-cresol	212	265	0.921	4.0	77.5
Pentachlorophenol	280	280	0.962	3.5	80.9
4-Nitrophenol	153	153	0.652	2.1	27.0
2,4-D	234	199	0.877	2.5	94.2
Silvex	280	196	0.987	2.4	93.7

TABLE II (cont'd)

EPA PRIORITY POLLUTANTS
MINIMUM DETECTION LIMITS & PERCENT RECOVERIES
 (1 L water/20 ppb)

<u>Base/Neutral Compounds</u>	<u>MWT</u>	<u>QUANT ION</u>	<u>RRT</u>	<u>MDL</u>	<u>% REC</u>
1,4-Dichlorobenzene	146	146	0.288	0.4	71.6
1,3-Dichlorobenzene	146	146	0.284	0.4	45.3
bis(2-Chloroisopropyl)ether	170	45	0.326	1.0	25.1
1,2-Dichlorobenzene	146	146	0.309	0.4	58.7
Nitrobenzene	123	77	0.348	0.5	30.3
N-Nitrosodi-n-propylamine	130	70	0.339	0.5	29.5
Hexachloroethane	234	117	0.354	2.0	83.2
Isophorone	138	82	0.389	0.4	98.2
bis(2-Chloroethoxy)methane	172	93	0.424	0.9	18.6
Naphthalene	128	128	0.460	0.4	55.9
1,2,4-Trichlorobenzene	180	182	0.454	1.3	61.7
Hexachlorobutadiene	258	225	0.506	0.5	61.6
Hexachlorocyclopentadiene	270	237	0.619	3.0	46.3
2-Chloronaphthalene	162	162	0.649	0.8	57.4
2,6-Dinitrotoluene	182	165	0.701	2.0	95.5
Dimethyl phthalate	194	163	0.712	1.0	100.0
Acenaphthylene	152	152	0.717	0.5	96.7
Acenaphthene	154	154	0.751	0.4	83.4
2,4-Dinitrotoluene	182	165	0.773	1.5	79.4
Diethyl phthalate	222	149	0.775	5.0	85.6
9H Fluorene	166	166	0.900	0.4	79.5
4-Chlorophenyl phenyl ether	204	204	0.849	1.0	97.5

TABLE II (cont'd)

<u>BASE/NEUTRAL COMPOUNDS</u>	<u>MWT</u>	<u>QUANT ION</u>	<u>RRT</u>	<u>MDL</u>	<u>% REC</u>
N-Nitrosodiphenylamine	198	169	0.868	0.4	67.0
1,2-Diphenyl hydrazine	184	77	0.877	0.6	75.9
4-Bromophenyl phenyl ether	248	248	0.937	0.5	70.7
Hexachlorobenzene	284	284	0.957	1.2	98.0
Phenanthrene	178	178	1.004	0.3	82.1
Anthracene	178	178	1.013	0.3	84.1
Di-n-butyl phthalate	278	149	1.138	0.4	76.3
Fluoranthene	202	202	1.193	0.6	88.5
Benzidene	184	184	1.211	10.0	68.0
Pyrene	202	202	1.250	0.5	88.8
Butylbenzyl phthalate	312	149	1.395	0.8	92.3
Chrysene	228	228	1.472	0.4	57.5
Benzo(a)anthracene	228	228	1.474	0.5	81.6
3,3-Dichlorobenzidene	252	252	1.470	0.7	69.6
Bis(2-ethylhexyl)phthalate	418	149	1.519	0.9	82.3
Di-n-octyl phthalate	386	149	1.637	1.5	95.3
Benzo(a)pyrene	252	252	1.657	0.3	69.7
Benzo(k)fluoranthene	252	252	1.661	0.4	63.1
Benzo(b)fluoranthene	252	252	1.712	0.6	53.4
Dibenzo(a,h)anthracene	278	278	1.967	4.0	50.2
Benzo(g,h,i)perylene	276	276	1.959	1.5	61.7
Indeno(1,2,3-CD)pyrene	276	276	1.966	1.3	71.2

TABLE II (cont'd)ADDITIONAL COMPOUNDS

<u>BASE/NEUTRAL COMPOUNDS</u>	<u>MWT</u>	<u>CHAR ION</u>	<u>RRT</u>	<u>MDL</u>	<u>% REC</u>
4-Methyl Pyridine	93	93,92,66	.165	1.4	42.3
Benzothophene	134	134,90	.464	0.4	52.0
Benzothiazole	135	135,90	.489	0.4	33.7
Isoquinoline	129	129,102	.525	1.7	9.7
Napthalene,1-Methyl	142	142,141	.588	0.8	27.4
Napthalene,1,2-Dimethyl	156	156,141	.695	2.0	64.1
Dibenzofuran	168	168,139	.782	0.8	43.7
Napthalene-1,6,7-Trimethyl	170	170,155	.831	0.8	83.4
Diethyl Phthalate	222	149,177	.841	5.0	83.5
2-Methyl Anthracene	192	192,189	1.107	1.2	55.0
Benzo(b)fluoranthene	252	252,136	1.761	0.6	56.8
Benzo(a)pyrene	252	252,136	1.822	0.4	60.6

TABLE III
ISOTOPICALLY LABELLED INTERNAL STANDARDS

<u>Compound</u>	<u>Natural Quant Ion</u>	<u>Deuterated Quant Ion</u>
<u>Acid Extractable</u>		
4-Chloro-3-methylphenol, 2.6-d ₂	142	144
2-Chlorophenol-3,4,5,6-d ₄	128	132
2,4-Dichlorophenol-3,5,6-d ₃	162	164
2,4-Dimethylphenol-3,5,6-d ₃	122	125
4,6-Dinitro-2-methylphenol-3,5-d ₂	198	200
2,4-Dinitrophenol-3,5,6-d ₃	184	187
2-Nitrophenol-3,4,5,6-d ₄	139	143
4-Nitrophenol-2,3,5,6-d ₄	139	143
Pentachlorophenol- ¹³ C ₆	266	272
Phenol-2,3,4,5,6-d ₅	94	99
2,4,6-Trichlorophenol-3,5-d ₂	196	198
<u>Base/Neutrals</u>		
Benz(a)anthracene-d ₁₂	228	240
Benzyl n-Butyl Phthalate-3,4,5,6-d ₄	149	153
Bis(2-chloroethoxy)-d ₈ -methane	93	101
Bis(2-ethylhexyl) Phthalate-3,4,5,6-d ₄	149	153
Dibenzo(a,h)anthracene-d ₁₄	278	292
1,2-Dichlorobenzene-d ₄	146	153
1,4-Dichlorobenzene-d ₄	146	153
Dimethyl Phthalate-3,4,5,6-d ₄	163	167
2,6-Dinitrotoluene-a,a,a-d ₃	165	168
Nitrobenzene-d ₅	123	128
1,2,3-Trichlorobenzene-4,5,6-d ₃	180	183
Acenaphthene-d ₁₀	154	164
Anthracene-d ₁₀	178	188
Benzo(k)fluoranthene-d ₁₂	252	264
Bis(2-chloroethyl)-d ₈ Ether	93	101
Chrysene-d ₁₂	228	240
Fluorene-d ₁₀	166	176
Naphthalene-d ₈	128	136
Pyrene-d ₁₀	202	212

EPA PRIORITY POLLUTANTS
EXTRACTABLE FRACTION - ANALYTICAL METHODOLOGY

EXTRACTION PROCEDURE

- 1) A 1 litre volume of sample water was spiked at the 10 ppb level with a mixture of deuterated standards (the sample was shaken and allowed to equilibrate for 1 hr at room temperature.
- 2) The pH was adjusted to a pH=11 using 6N NaOH and the sample extracted with three 50 ml volumes of CH_2Cl_2 .
- 3) The aqueous portion was then acidified to pH=2 using 6N HCl and extracted with 3 x 50 ml volumes of CH_2Cl_2 to extract the acidic and phenolic compounds.
- 4) Similar organic extracts were combined and dried through a column of solvent washed Na_2SO_4 (acidified Na_2SO_4 for acid fraction).
- 5) The dried extracts were collected in 1 litre Kuderna-Danish evaporators containing 2 mls of isooctane then concentrated to a volume of approximately 10 ml.
- 6) The extracts were transferred to 15 ml graduated centrifuge tube (a 2 x 1 ml isooctane rinse) then concentrated to a 10 ml volume using a gentle stream of N_2 and spiked with 10 ppb D_{10} Phenanthrene.

Gas Chromatographic/Mass Spectrometry
Instrumentation

One ul aliquots of the 10 ml extracts were analysed for the presence of the selected priority pollutants using a Finnigan 4500 GC/MS system set to the following condition:

All injections were performed using an on column technique.

MASS SPECTROMETER

Electron Multiplier	- 1450 e.v.
Ionization Energy	- 70 e.v.
Sensitivity	- 10^8 amps/volt
Scan Rate	- 2.25 mSec/mass unit
Scan Range	- 1-2000
Mass Range	- 60-450 a.m.u.

Varian Gas Chromatograph Conditions

Instrument	- Varian 3500
GC Column	- DB-5 30 M capillary
GC Temp Program	
Initial	- 50°C (0.1 min)
Final	- 2850C (20 min)
Rate	- 10°C/min
Injection Port Temp	- 250°C
Column Carrier Gas	- Helium

EXTRACTABLE (EPA) ANALYSIS - WATER SAMPLES

Standard Compound Characterization

A Standard solution containing approximately 1.0 ng/ul of each of the selected priority pollutants was prepared and analysed by GC/MS to determine each compound's fragmentation pattern, relative retention time (RRT) and relative response factor (RRF) compared to the internal standard D₁₀ Phenanthrene. A 10 ppb dilution of this standard was routinely run prior to sample analysis to insure optimum performance of the GC/MS system. The minimum detection limit (MDL) represents the minimum level at which a compound can be detected and quantitated. Values were determined by comparison of the response of the labelled internal standards to the level of background interference in the region of the corresponding natural compound. These values are averages obtained from actual sample matrices.

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EPA PRIORITY POLLUTANTS

MINIMUM DETECTION LIMITS & PERCENT RECOVERIES

(1 L water/20 ppb)

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		<u>ION</u>	<u>RRT</u>		
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Benzo(g,h,i)perylene	276	276	1.959	1.5	61.7
Indeno(1,2,3-CD)pyrene	276	276	1.966	1.3	71.2

VOLATILE ANALYSIS - WATER SAMPLES

Sampling Preparation - Collection and Handling

Water samples for purgeable organics were collected in 50 ml capacity amber glass bottles equipped with Tuf-Bond discs and screw caps with a syringe access hole in the centre. The bottles had been previously cleaned and heated at 200°C for at least 4 hours, purged with nitrogen and sealed with PTFE coated silicone and open top caps prior to transportation to the sampling sites.

The bottles were filled to slight overflow, then sealed so that no air bubble was present in the sample. They were immediately returned to Mann Testing Labs and stored at 4°C until analysed.

Preparation of Standard Solutions

Stock standard solutions were prepared by injecting appropriate amounts of each pollutant into 25 ml of glass distilled methanol (Burdick and Jackson) in reactiflasks fitted with Minnert valves (Chromatographic Specialties Ltd.) which provide complete protection and easy access via a hypodermic needle. The resulting concentration of 1 mg/ml was further diluted to give methanolic solutions of 400 ug/ml, 40 ug/ml and 4 ug/ml for each component. Gaseous standards were prepared in a similar manner by injecting the gaseous compound from a 10 ml gas tight syringe into a pre-weighed reactiflask filled with 25 ml of methanol. The syringe needle was slightly above the ethanol meniscus while injecting, hence enabling the gas to dissolve rapidly into the methanol. The flask was re-weighed again to determine the amount

in the solution.

Aqueous composite standards were prepared by injecting appropriate aliquots of methanolic standard in 250 ml sample bottles filled with purified water.

The relative retention times (RRT) were compared to that of the internal standard, deuterated chlorobenzene (RRT = 1.00) which eluted close to the middle of the chromatogram. Detection limits were determined by purging aqueous composite standard mixture at various concentrations.

Instrumentation

Analysis of volatile organics in water was conducted using a UNACON 780B automatic concentrator (Envirochem Inc., Kemblesville, P.A.). This instrument utilized the technique developed by Bellar and Lichtenberg for the isolation and concentration of volatiles for chromatographic analysis. In general, this process involved gas stripping of the sample and adsorption of the organic compounds on a sorbent trap followed by thermal desorption and analysis by gas chromatography or gas chromatography/mass spectrometry.

The sample purging assembly included a sparger vial with a side port which was equipped with an open top screw cap and Tuf-Bond septum. A 30 ml vial was used to obtain detection limits as reported. Sample was transferred to the vial through a transfer line by pressurizing the sample bottle which was inverted and clamped on the side of the instrument. The transfer line was constructed of 1/16" teflon tubing with two Luer Lock

connectors at each end. Two 17-gauge needles were used to puncture the septa of both the bottle and the side port.

Prior to the start of the analysis, the sparger vial was purged with helium for 5 minutes by rotating the valve to "Trap-Out" mode. In this position, any contaminants that were present in the sparger vial were purged out of the system without entering the trap. An appropriate aliquot of the water was then transferred to the sparger and purged for 15 minutes at the "Trap-In" mode. The trap was heat desorbed and the organics backflushed into the second trap. When this transfer process was completed, the second trap was again heated, releasing all adsorbed organics into the capillary GC/MS system for identification and quantification.

The MDL (Method Detection Limit) listed in the volatile section is the limit that the compound can be identified and quantified in the sample matrix using the purge & trap GC/MS method.

QA/QC

Prior to sample analysis reference standards were analyzed to determine the instrument response for standards of known levels. Instrument blanks were then analyzed to determine the extent of any instrument contamination. Travelling blanks for each set of samples were analyzed to measure any possible background contamination caused by the sample container. At ten sample intervals duplicate samples were analyzed to monitor the analytical reproducibility.

TABLE I
RETENTION DATA, % RECOVERY & CHARACTERISTIC
IONS OF THE VOLATILE ORGANICS

Compound	RRT	% RECOVERY	PRIMARY ION (m/e)	SECONDARY IONS (m/e)
Dichlorodifluoromethane	0.477	99.8	85	87
Chloromethane	0.486	100.3	50	52
Vinyl Chloride	0.495	106.2	62	64
Bromomethane	0.511	105.0	94	96
Chloroethane	0.516	91.9	64	96
Trichlorofluoromethane	0.545	101.6	101	103
1,1-Dichloroethylene	0.568	98.6	61	63,96
Dichloromethane	0.571	92.7	49	84
t-1,2-Dichloroethylene	0.608	92.3	61	63,96
1,1-Dichloroethane	0.614	97.2	63	65,83
Chloroform	0.661	90.5	83	85,87
1,2-Dichloroethane	0.690	80.3	62	64,98
1,1,1-Trichloroethane	0.707	102.5	97	61,99
Benzene	0.729	97.5	78	51,77
Carbon Tetrachloride	0.737	97.6	117	119,121
1,2-Dichloropropane	0.769	91.2	63	62,76
Bromodichloromethane	0.779	94.2	83	82,129
Trichloroethylene	0.782	101.2	95	130
1,3-Dichloropropene(Z)	0.827	90.8	75	110
1,3-Dichloropropene(E)	0.857	78.9	75	110
1,1,2-Trichloroethane	0.866	71.1	83	97
Toluene	0.888	91.4	91	92
Dibromochloromethane	0.914	79.7	129	127
Tetrachloroethylene	0.960	126.2	129	166,131
Chlorobenzene	1.003	92.7	112	77,114
Ethyl Benzene	1.026	93.9	91	106
m,p-Xylenes	1.038	95.4	91	105,106
Bromoform	1.042	52.5	173	171,175
o-Xylene	1.067	88.3	91	105,106
1,1,2,2-Tetrachloroethane	1.066	45.0	83	85
1,3-Dichlorobenzene	1.199	86.4	146	148,111
1,4-Dichlorobenzene	1.204	86.7	146	148,111
1,2-Dichlorobenzene	1.231	85.4	146	148,111
Acrolein	0.528	22.1	56	55
Acrylonitrile	0.551	7.9	53	52
Pentane	0.512	82.7	43	42,57
Dimethyl Sulphide	0.518	80.2	47	62,45
Methylethylketone	0.591	8.8	43	72
Hexane	0.622	84.3	57	41,43
Heptane	0.787	97.8	43	57,71
4-Methyl-2-pentanone	0.823	26.6	43	58,85

TABLE I(cont'd)

**REPRODUCIBILITY OF SELECTED VOLATILE
ORGANICS USING PURGE & TRAP SYSTEM**

Compound	Ion (m/e)	Peak Intensity			SDV	% C.V.
		Run#1	Run#2	Run#3		
Dichlorodifluoromethane	85	41408	46016	47488	3171.9	7.1
Chloromethane	50	19840	18560	19072	644.3	3.4
Vinyl Chloride	62	81664	83072	89728	4307.2	5.1
Bromomethane	94	49536	52608	66048	8781.8	15.7
Chloroethane	64	39872	35648	47616	6069.7	14.8
Trichlorofluoromethane	101	100992	93568	123008	15310.9	14.5
1,1-Dichloroethylene	61	22848	21600	20832	1017.5	4.7
Dichloromethane	84	24096	20512	20896	1967.8	9.0
t-1,2-Dichloroethylene	61	32032	28064	27776	2378.4	8.1
1,1-Dichloroethane	63	54272	48064	50496	3128.2	6.1
Chloroform	83	55168	52160	46528	4385.9	8.6
1,2-Dichloroethane	62	31904	31296	35840	2467.8	7.5
1,1,1-Trichloroethane	97	48256	50432	51008	1451.5	2.9
Benzene	78	99200	93184	105984	6403.8	6.4
Carbon Tetrachloride	117	37824	37248	40896	1961.2	5.1
1,2-Dichloropropane	63	21984	20768	24064	1666.8	7.5
Bromodichloromethane	83	48640	51136	51136	1441.1	2.9
Trichloroethylene	130	46208	43072	46208	1810.6	4.0
1,3-Dichloropropene(Z)	75	38272	38848	40320	1056.2	2.7
1,3-Dichloropropene(E)	75	28704	25696	30400	2382.3	8.4
1,1,2-Trichloroethane	97	36672	32416	38848	3271.6	9.1
Toluene	91	145408	140544	145664	2885.0	2.0
Dibromochloromethane	129	47808	43200	52096	4449.0	9.3
Tetrachloroethylene	129	66176	64448	66816	1224.9	1.9
Chlorobenzene	112	104960	101248	96640	4168.0	4.1
Ethyl Benzene	91	139008	124032	135168	7778.6	5.9
m,p-Xylenes	91	111104	99584	117120	8910.8	8.2
Bromoform	173	34240	30336	30528	2200.6	6.9
o-Xylene	91	121856	113152	124032	5757.2	4.8
1,1,2,2-Tetrachloroethane	83	37312	33984	31072	3122.3	9.2
1,3-Dichlorobenzene	146	99584	88192	101504	7195.8	7.5
1,4-Dichlorobenzene	146	114304	101248	118400	8957.6	8.0
1,2-Dichlorobenzene	146	94976	86144	94464	4958.0	5.4
Acrolein	56	3452	2636	2872	419.9	14.1
Acrylonitrile	53	6024	4592	4984	740.0	14.2
Pentane	43	82048	71808	71296	6065.3	8.1
Dimethyl Sulphide	62	64384	56896	60544	3744.4	6.2
Methylethylketone	43	17024	23136	20757	3080.9	15.2
Hexane	57	66944	73472	84608	8931.6	11.9
Heptane	43	117248	123648	125824	4458.0	1.6
4-Methyl-2-pentanone	43	53440	64448	51904	6842.1	12.1

TABLE I (cont'd)

GC/MS
% RECOVERY REPRODUCIBILITY
5 ppb level

	% Recovery Run #1	% Recovery Run #2	% Recovery Run #3	Ave. % Recovery	SDV
Dichlorodifluoromethane	93.6	101.6	104.1	99.8	5.5
Chloromethane	88.7	99.1	113.2	100.3	12.3
Vinyl Chloride	92.1	112.1	114.4	106.2	12.3
Bromomethane	95.4	108.6	111.0	105.0	8.4
Chloroethane	93.8	91.9	90.0	91.9	1.9
Trichlorofluoromethane	105.6	95.8	103.3	101.6	5.1
1,1-Dichloroethylene	97.1	99.1	99.7	98.6	1.4
Dichloromethane	96.2	93.1	88.7	92.7	3.8
t-1,2-Dichloroethylene	88.1	91.8	96.9	92.3	4.4
1,1-Dichloroethane	93.2	103.1	95.4	97.2	5.2
Chloroform	97.4	92.1	82.1	90.5	7.8
1,2-Dichloroethane	75.0	73.5	92.5	80.3	10.6
1,1,1-Trichloroethane	100.8	101.5	105.3	102.5	2.4
Benzene	96.3	101.2	95.0	97.5	3.3
Carbon Tetrachloride	95.5	94.0	103.2	97.6	4.9
1,2-Dichloropropane	90.0	85.1	98.6	91.2	6.8
Bromodichloromethane	99.0	92.0	91.6	94.2	4.2
Trichloroethylene	103.9	97.5	102.1	101.2	3.3
1,3-Dichloropropene (Z)	87.3	88.6	96.4	90.8	4.9
1,3-Dichloropropene (E)	81.4	72.9	82.5	78.9	5.3
1,1,2-Trichloroethane	73.7	65.1	74.6	71.1	5.2
Toluene	93.7	90.6	89.9	91.4	2.0
Dibromochloromethane	81.2	73.3	84.7	79.7	5.8
Tetrachloroethylene	127.3	125.2	126.1	126.2	1.1
Chlorobenzene	96.4	92.9	88.7	92.7	3.9
Ethyl Benzene	95.8	92.5	93.5	93.9	1.7
m,p-Xylenes	98.1	91.5	96.6	95.4	3.5
Bromoform	56.7	50.2	50.5	52.5	3.7
o-Xylene	90.5	89.7	84.7	88.3	3.2
1,1,2,2-Tetrachloroethane	46.6	42.5	46.0	45.0	2.2
1,3-Dichlorobenzene	86.4	88.4	84.3	86.4	2.1
1,4-Dichlorobenzene	86.5	88.4	85.3	86.7	1.6
1,2-Dichlorobenzene	88.8	82.6	84.7	85.4	3.2
Acrolein	24.6	19.9	21.7	22.1	2.4
Acrylonitrile	9.2	7.0	7.6	7.9	1.1
Pentane	86.1	78.8	83.2	82.7	3.7
Dimethyl Sulphide	79.3	78.9	82.4	80.2	1.9
Methylethylketone	8.5	10.9	6.9	8.8	2.0
Hexane	85.9	81.8	85.2	84.3	2.2
Heptane	99.6	95.9	97.8	97.8	1.9
4-Methyl-2-pentanone	25.4	27.8	26.6	26.6	1.2

TABLE I (cont'd)

RETENTION TIME REPRODUCIBILITY

	Run #1 RRT	Run #2 RRT	Run #3 RRT	Ave. RRT	+ Limits For RRT
Dichlorodifluoromethane	0.488	0.473	0.471	0.477	0.012
Chloromethane	0.496	0.482	0.480	0.486	0.012
Vinyl Chloride	0.506	0.491	0.487	0.495	0.012
Bromomethane	0.520	0.507	0.505	0.511	0.010
Chloroethane	0.524	0.513	0.511	0.516	0.010
Trichlorofluoromethane	0.549	0.544	0.542	0.545	0.005
1,1-Dichloroethylene	0.571	0.568	0.565	0.568	0.005
Dichloromethane	0.575	0.570	0.569	0.571	0.005
t-1,2-Dichloroethylene	0.609	0.608	0.607	0.608	0.002
1,1-Dichloroethane	0.614	0.614	0.613	0.614	0.002
Chloroform	0.660	0.662	0.660	0.661	0.002
1,2-Dichloroethane	0.694	0.682	0.693	0.690	0.009
1,1,1-Trichloroethane	0.708	0.710	0.704	0.707	0.004
Benzene	0.731	0.733	0.723	0.729	0.008
Carbon Tetrachloride	0.739	0.741	0.731	0.737	0.005
1,2-Dichloropropane	0.773	0.774	0.760	0.769	0.010
Bromodichloromethane	0.783	0.784	0.770	0.779	0.010
Trichloroethylene	0.786	0.787	0.772	0.782	0.010
1,3-Dichloropropene (Z)	0.832	0.833	0.817	0.827	0.010
1,3-Dichloropropene (E)	0.862	0.863	0.846	0.857	0.012
1,1,2-Trichloroethane	0.873	0.873	0.851	0.866	0.012
Toluene	0.892	0.892	0.881	0.888	0.005
Dibromochloromethane	0.915	0.916	0.910	0.914	0.005
Tetrachloroethylene	0.960	0.960	0.959	0.960	0.002
Chlorobenzene	1.003	1.003	1.002	1.003	0.002
Ethyl Benzene	1.027	1.026	1.026	1.026	0.002
m,p-Xylenes	1.038	1.038	1.037	1.038	0.002
Bromoform	1.042	1.042	1.041	1.042	0.002
o-Xylene	1.066	1.068	1.068	1.067	0.002
1,1,2,2-Tetrachloroethane	1.066	1.066	1.066	1.066	0.001
1,3-Dichlorobenzene	1.201	1.200	1.197	1.199	0.003
1,4-Dichlorobenzene	1.206	1.205	1.202	1.204	0.003
1,2-Dichlorobenzene	1.232	1.232	1.229	1.231	0.003
Acrolein	0.534	0.525	0.524	0.528	0.007
Acrylonitrile	0.555	0.550	0.548	0.551	0.005
Pentane	0.507	0.519	0.511	0.512	0.008
Dimethyl Sulphide	0.512	0.526	0.517	0.518	0.009
Methylethylketone	0.585	0.597	0.592	0.591	0.007
Hexane	0.617	0.626	0.623	0.622	0.006
Heptane	0.784	0.790	0.787	0.787	0.004
4-Methyl-2-pentanone	0.821	0.826	0.823	0.823	0.004

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B3.2.3 ANALYTICAL METHODS AND QA/QC PROCEDURES

ISOTOPE LABORATORY, UNIVERSITY OF WATERLOO

TABLE B3-3 - SUMMARY OF ISOTOPE ANALYTICAL METHODOLOGIES

<u>Parameter</u>	<u>Reference</u>	<u>Comments</u>
deuterium	Thurston, W.M. (1971)	● modernization of equipment ● see Fritz, P. et al (1986) for additional comments ● precision is $+ 1^{\circ}/\text{‰}$ ● all results as $\bar{8}^{\circ}/\text{‰}$ relative to SMOW
oxygen-18	Moser, H. (editor) (1977)	● modernization of equipment ● see Fritz, P. et al (1986) for additional comments ● precision is $+ 0.15^{\circ}/\text{‰}$ ● all results as $^{\circ}/\text{‰}$ relative to SMOW
normal tritium	Desaulniers, D.E. et al (1981)	● all samples were distilled prior to mixing with Insta-Gel ● detection limit is 6 ± 8 T.U.
enriched tritium	Taylor, C.B. (1976)	● 300 mL concentrated to 15 mL ● detection limit is 0.8 ± 0.8 T.U.
carbon-13	Berry, J.C. and Drimmie, R.J. (1982)	● precision is $+ 0.05^{\circ}/\text{‰}$ ● all results as $^{\circ}/\text{‰}$ relative to PDB

NOTES:

1. NBS standards are analyzed with every run.
2. Standards and background are analyzed with every run for tritium
3. Duplicates are analyzed every 6 to 10 samples.

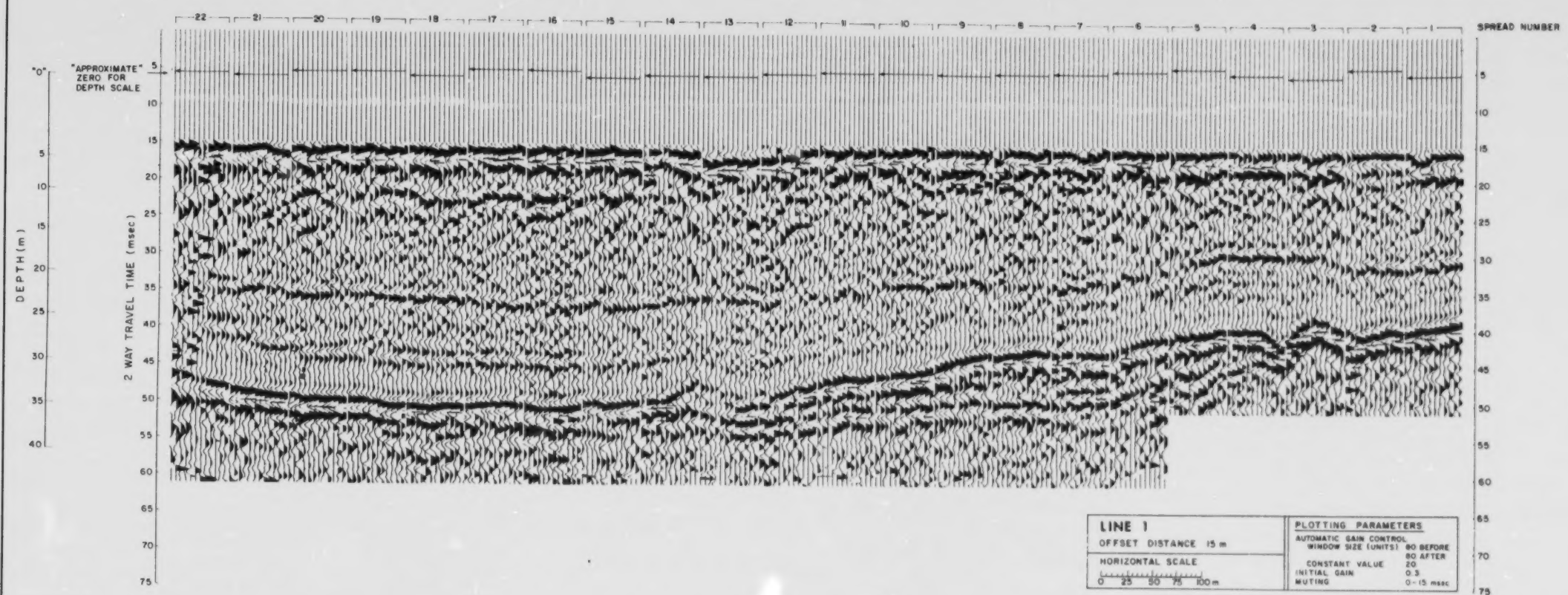
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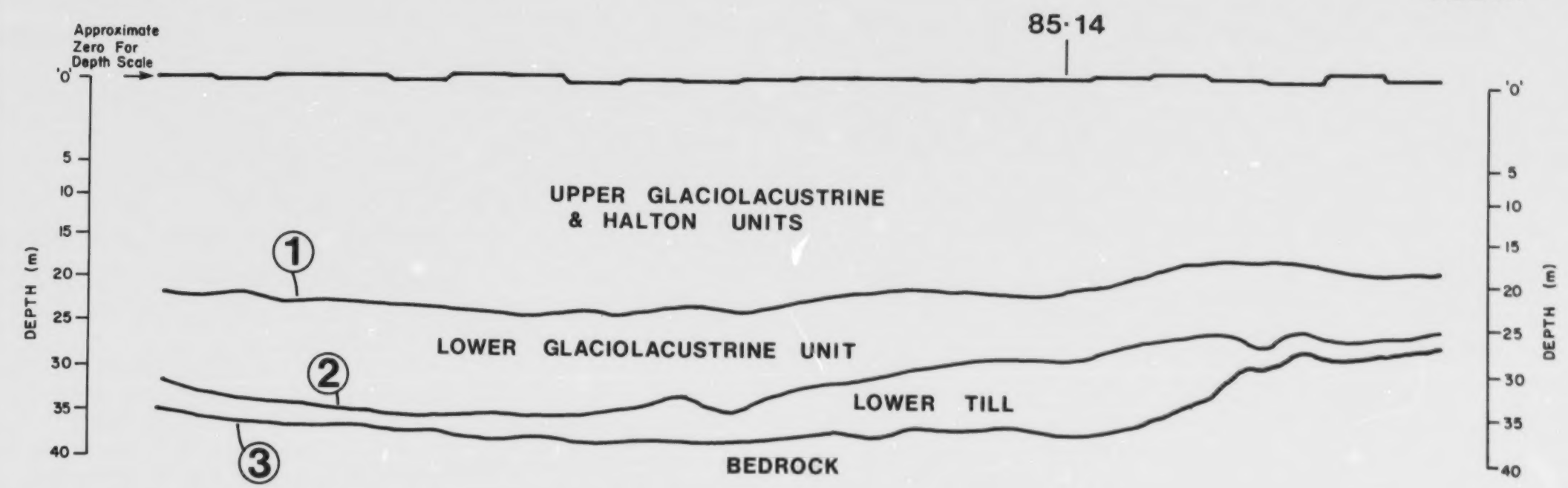
B3.2.4 ANALYTICAL METHODS AND QA/QC PROCEDURES

TRITIUM LABORATORY, UNIVERSITY OF MIAMI



NORTH

SOUTH



OWMC Ontario Waste Management Corporation

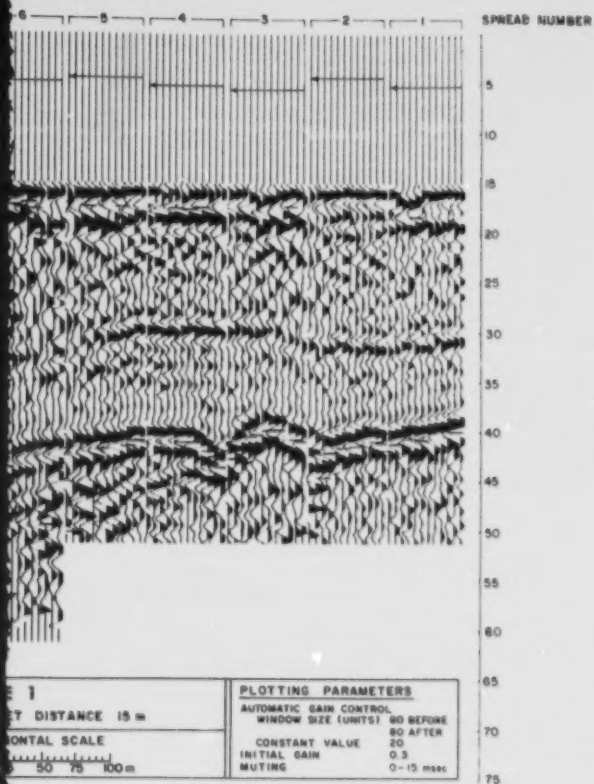
Consultant:



Legend:

- ① Reflective Horizon Number 1
- ② Reflective Horizon Number 2
- ③ Reflective Horizon Number 3

85-14 Borehole Location



SOUTH

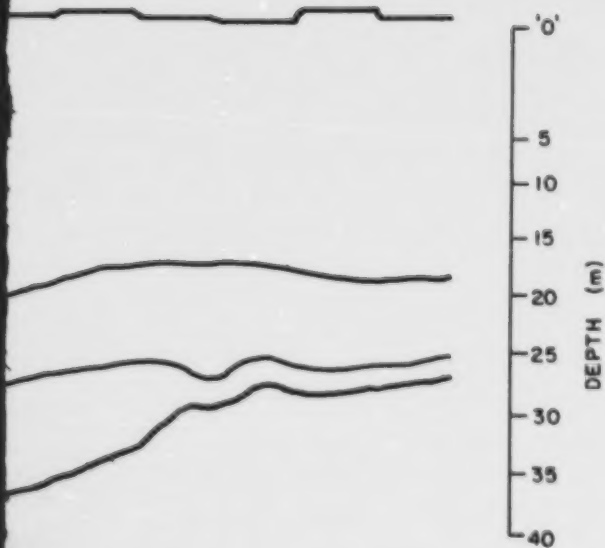
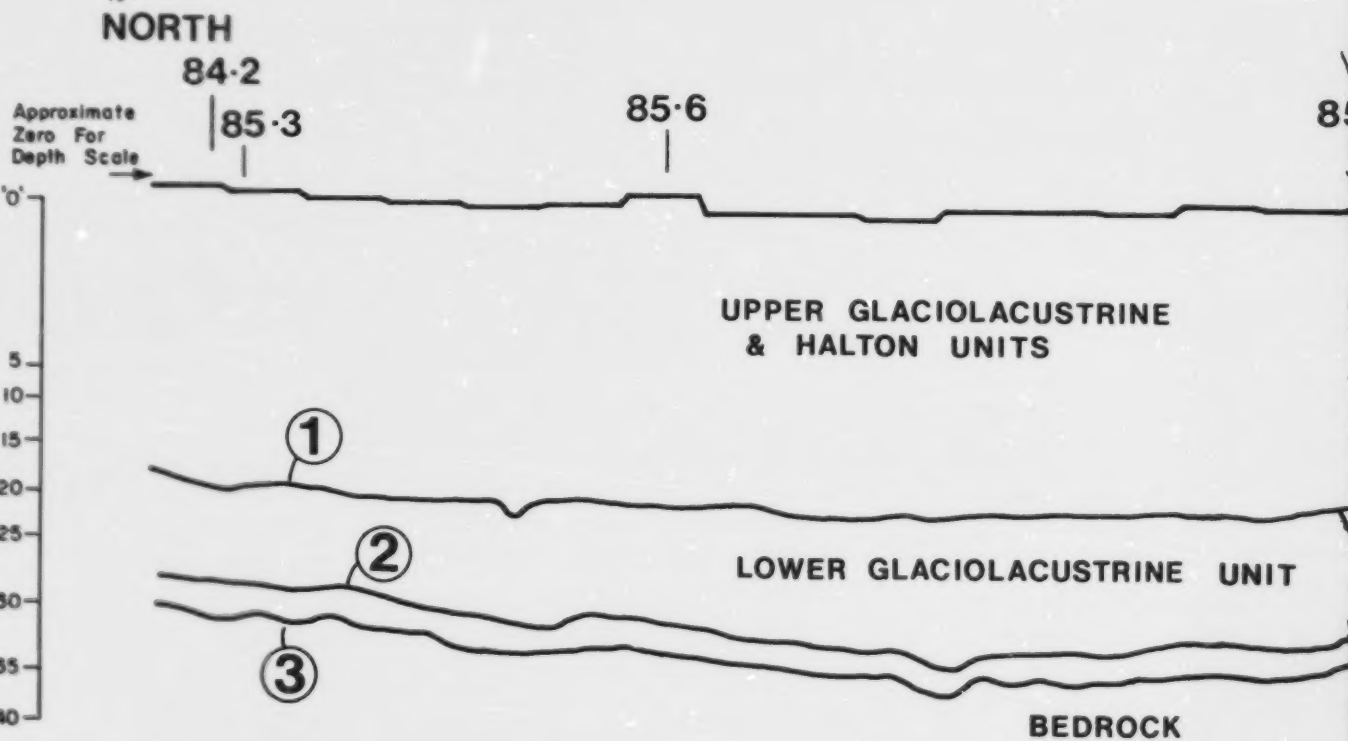
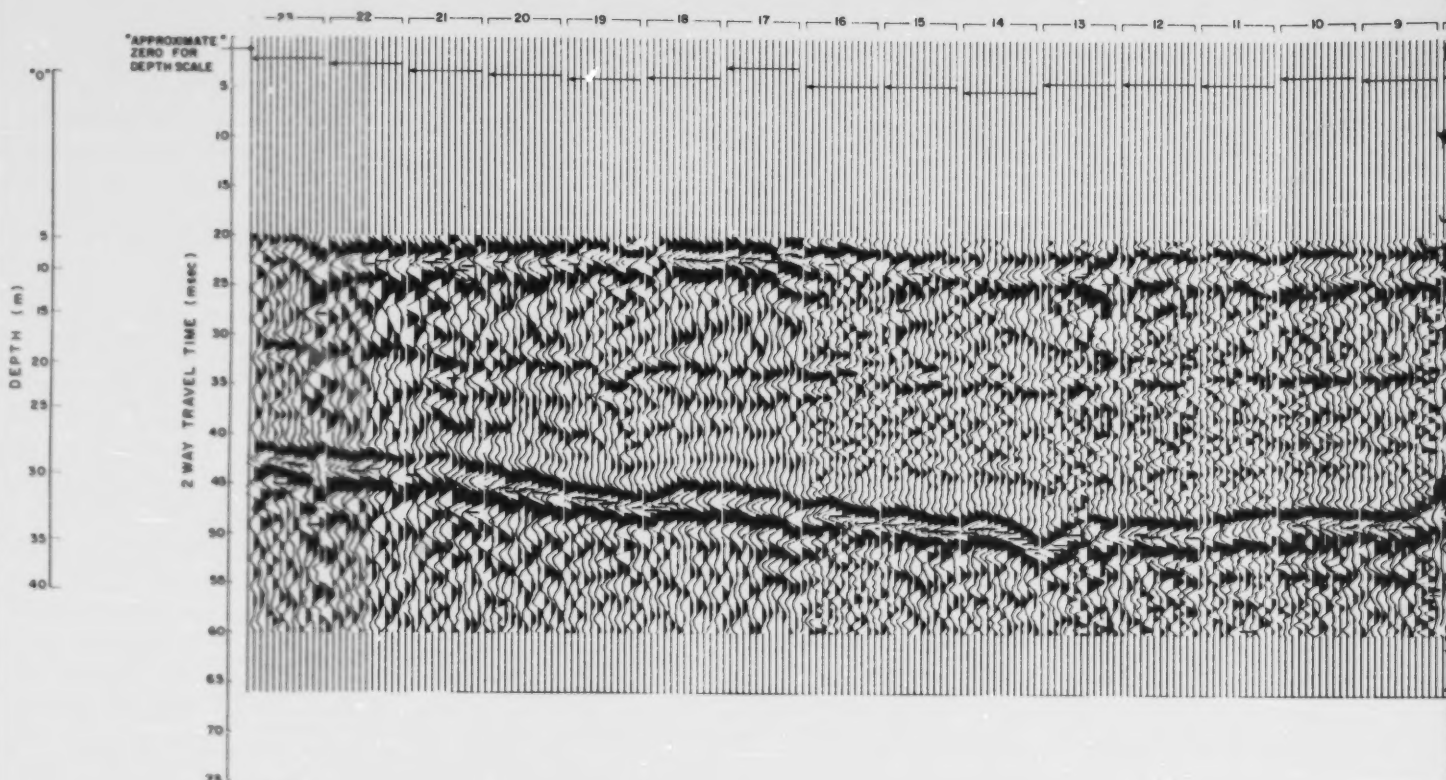


FIGURE D5-1

Seismic Cross-Section Line 1



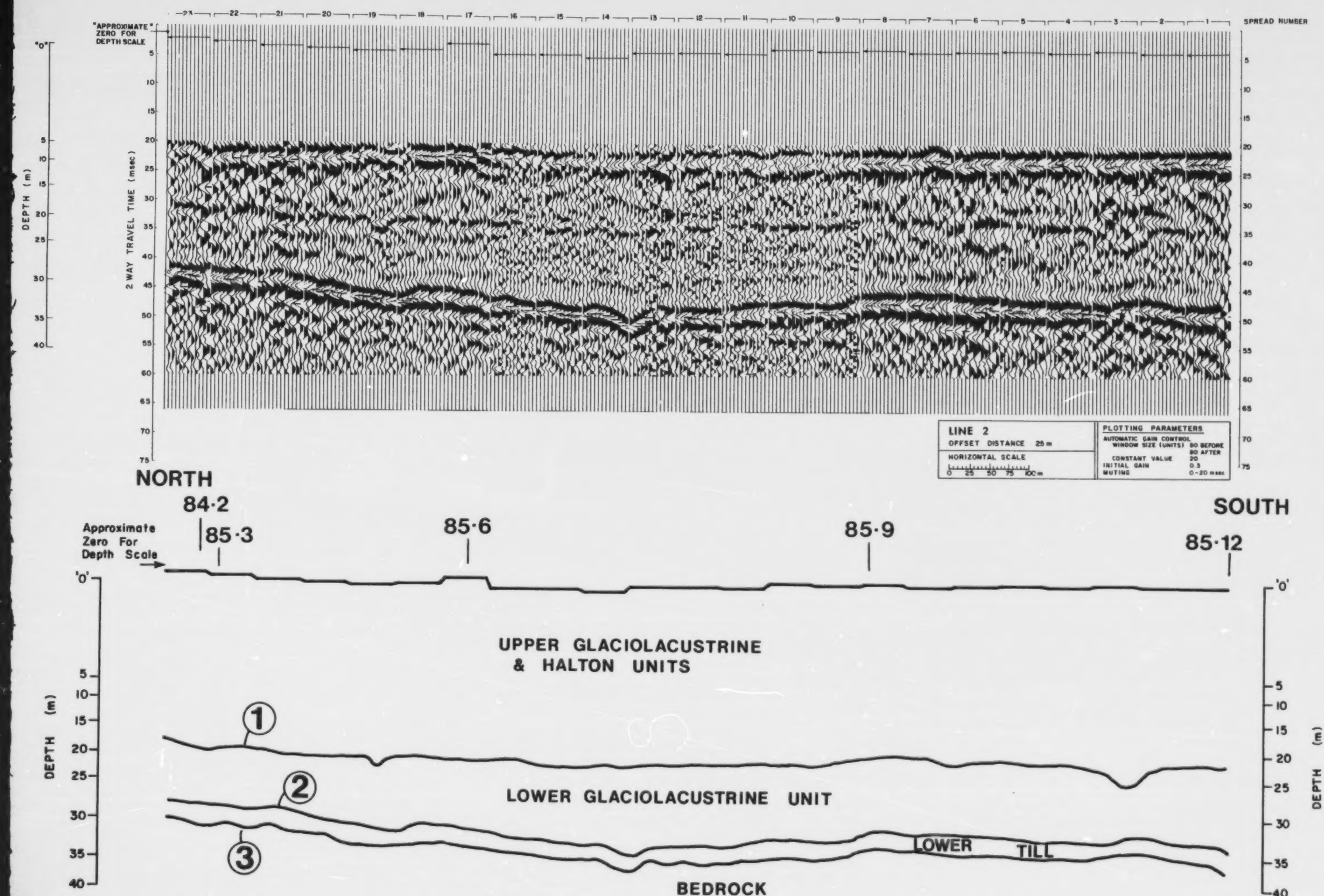
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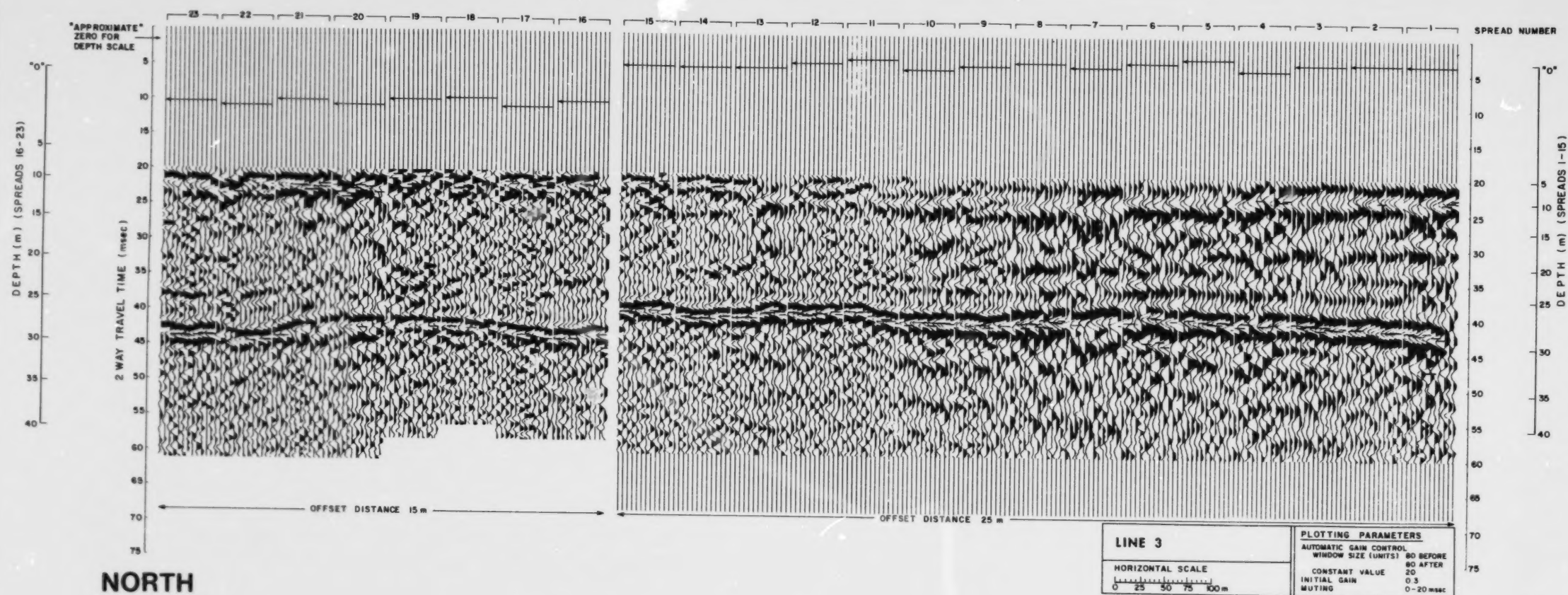
WATERLOO
GEOPHYSICS**Legend:**

- ① Reflective Horizon Number 1
- ② Reflective Horizon Number 2
- ③ Reflective Horizon Number 3

85.14 Borehole Location

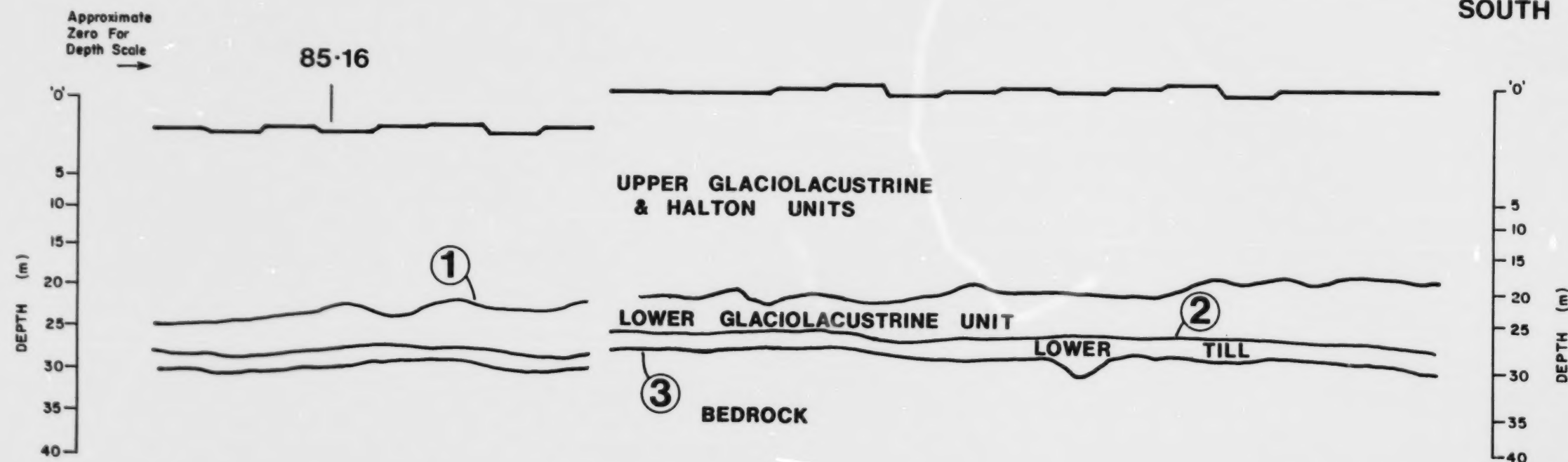
FIGURE D5-2

**Seismic
Cross-Section
Line 2**




NORTH

SOUTH

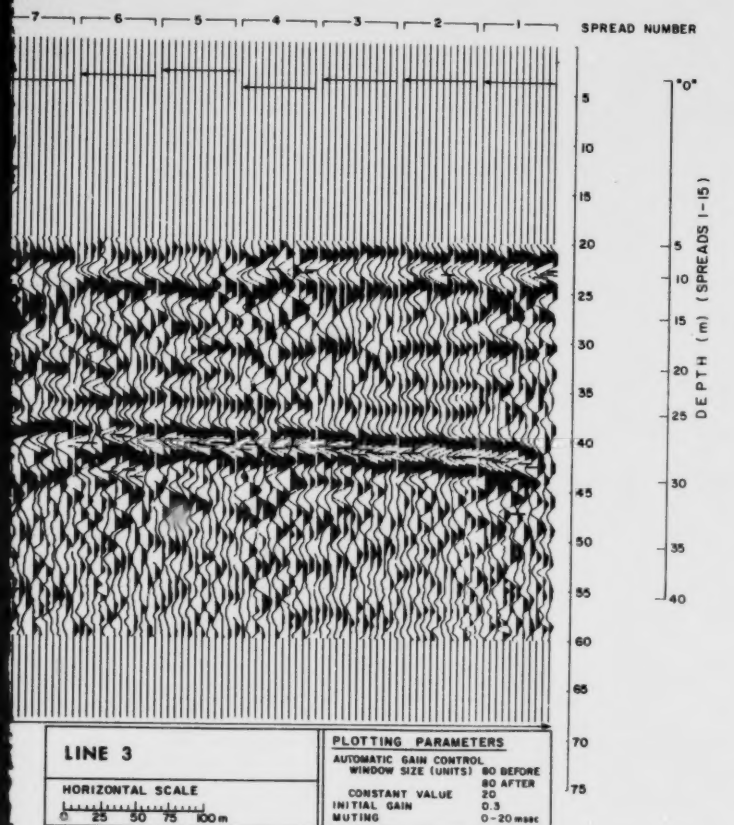
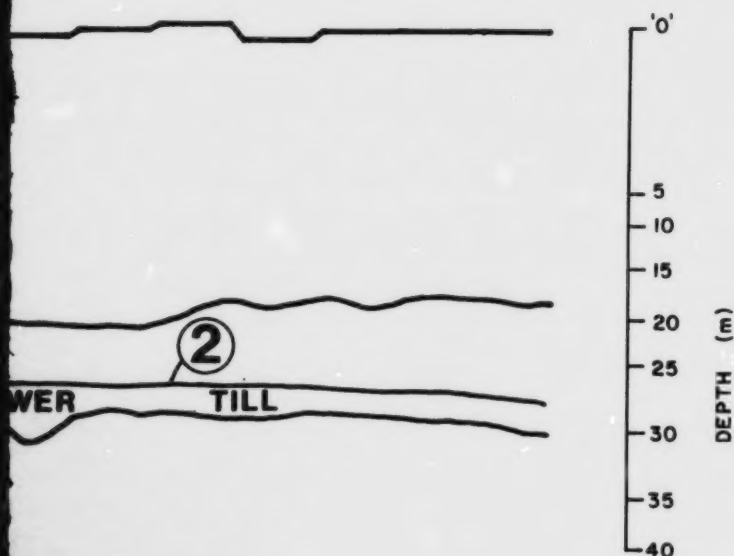


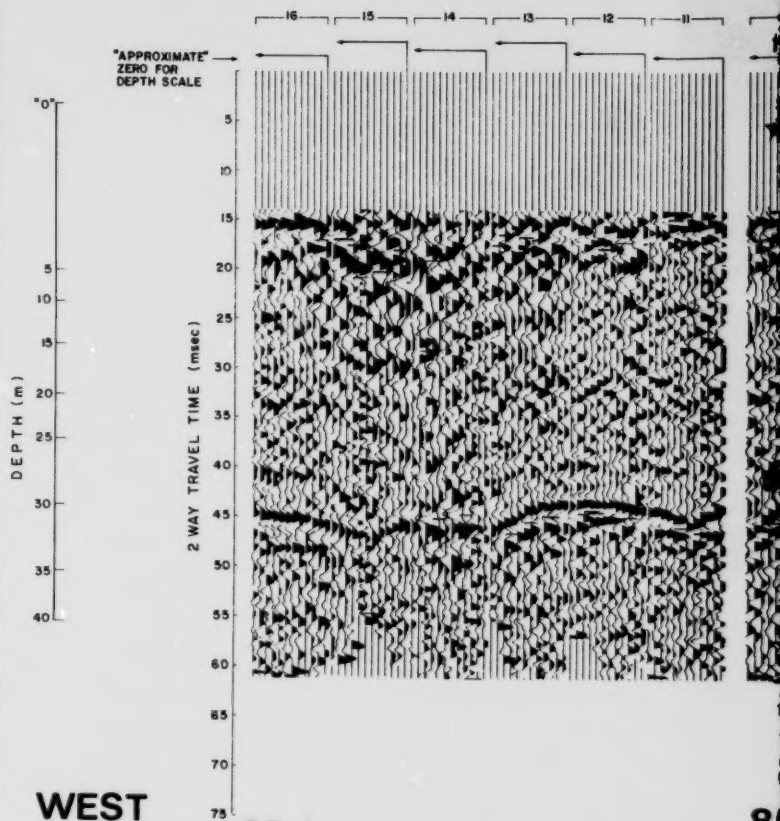
Consultant:

WATERLOO
GEOPHYSICS**Legend :**

- ① Reflective Horizon Number 1
- ② Reflective Horizon Number 2
- ③ Reflective Horizon Number 3

85-14 Borehole Location

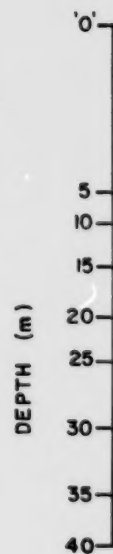
**SOUTH****FIGURE D5-3**
**Seismic
Cross-Section
Line 3**



WEST

Approximate
Zero For
Depth Scale

85.1



UPPER
& HALT

LOWER GLACIO

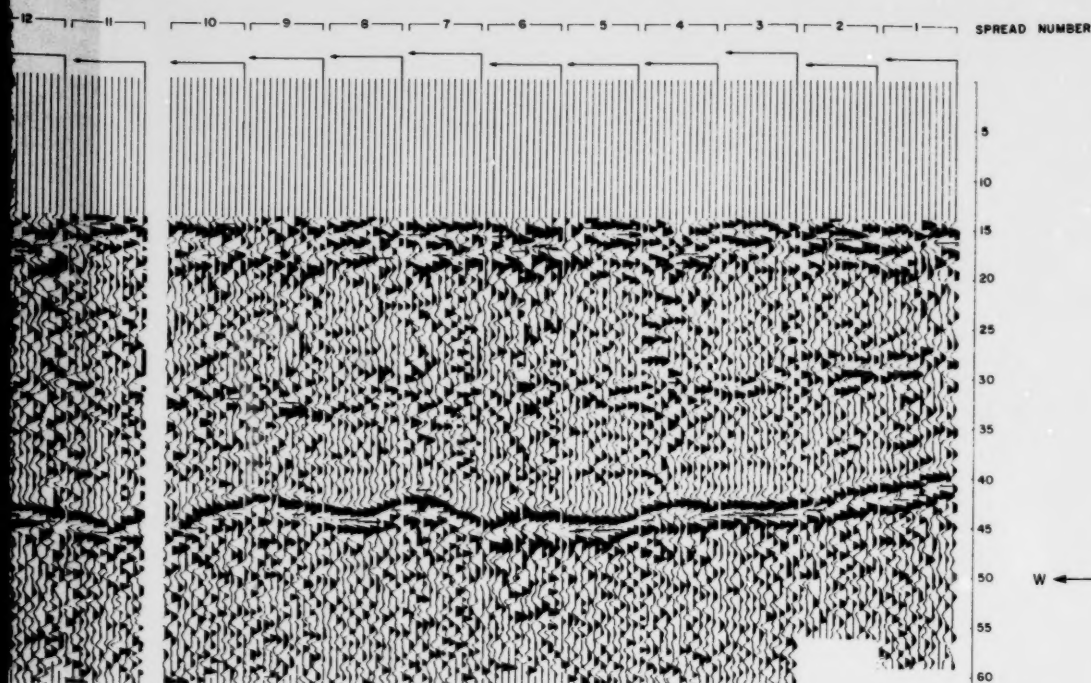
BED

Consultant:

WATERLOO
GEOPHYSICS**Legend:**

- ① Reflective Horizon Number 1
 ② Reflective Horizon Number 2
 ③ Reflective Horizon Number 3

85-14 Borehole Location



LINE 4		PLOTting PARAMETERS	
OFFSET DISTANCE 25m		AUTOMATIC GAIN CONTROL	
HORIZONTAL SCALE		WINDOW SIZE (UNITS) 80 BEFORE	
0 25 50 75 100m		80 AFTER	
		CONSTANT VALUE 20	
		INITIAL GAIN 0.3	
		MUTING 0-14 msec	

85-2

EAST

UPPER GLACIOLACUSTRINE
& HALTON UNITS

ER GLACIOLACUSTRINE UNIT

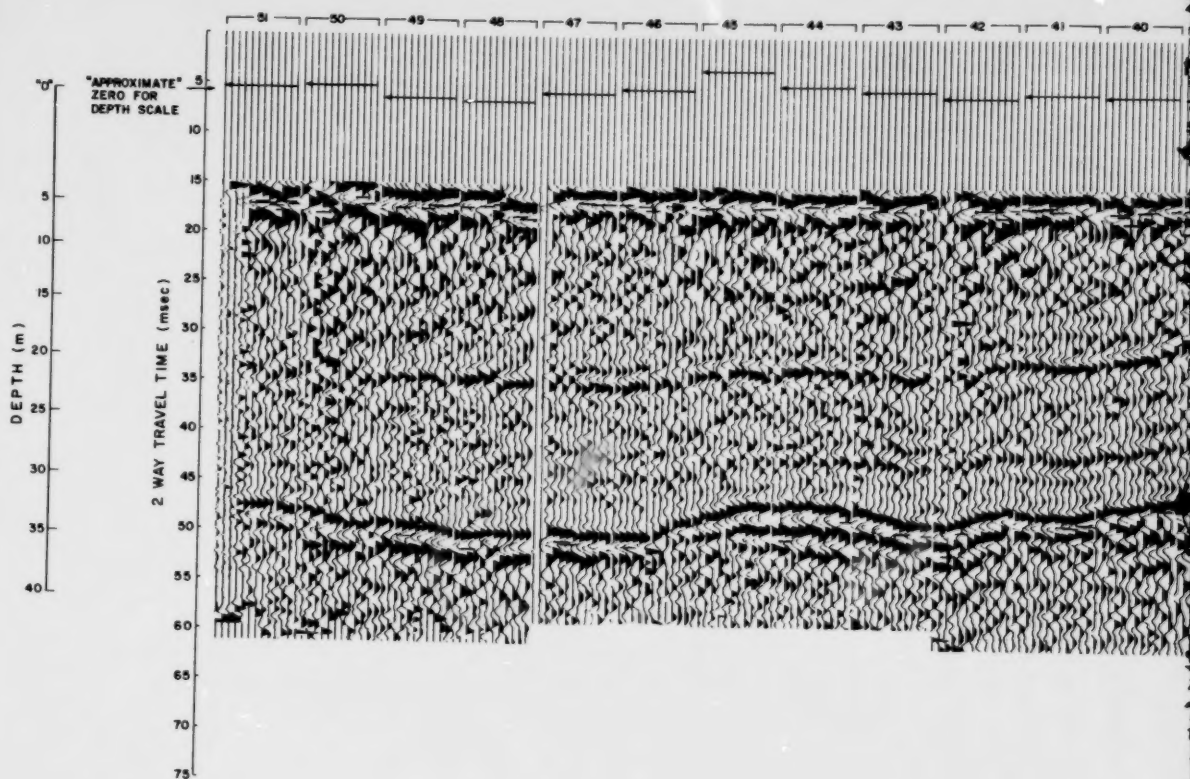
LOWER TILL

BEDROCK

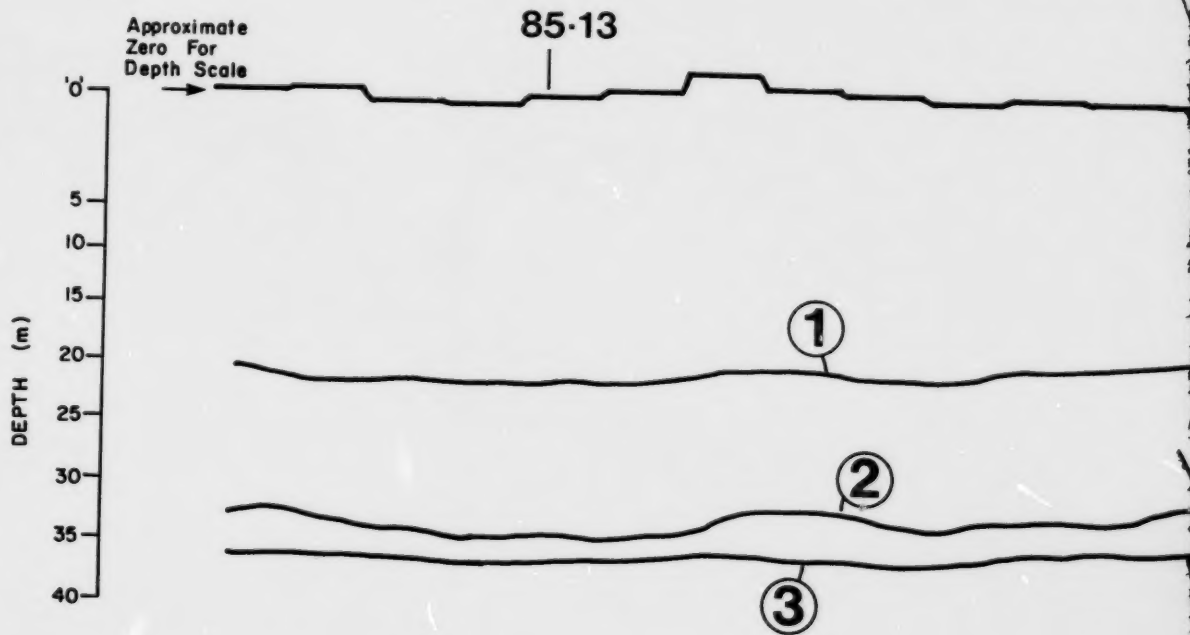
 0
5
10
15
20
25
30
35
40
DEPTH (m)

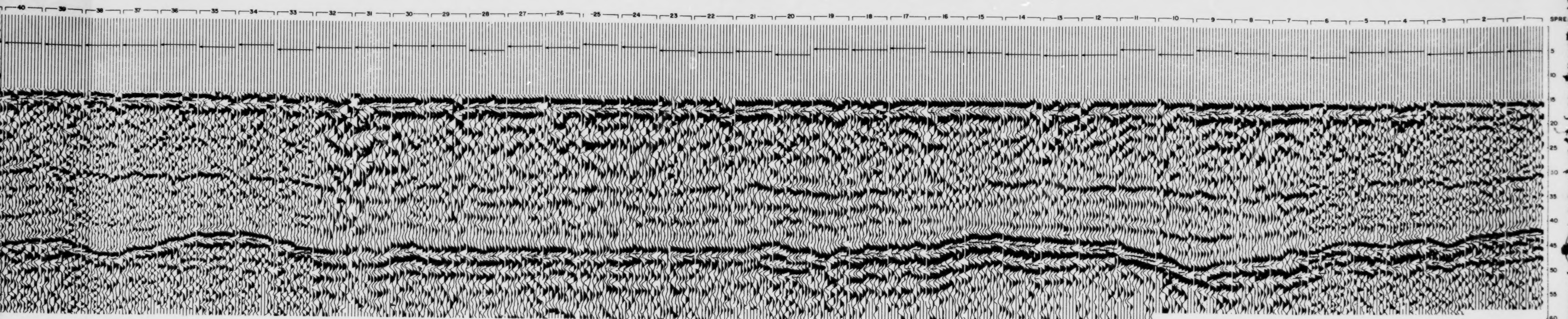
FIGURE D5-4

**Seismic
Cross-Section
Line 4**



EAST





LINE 5		PLOTING PARAMETERS	
OFFSET	DISTANCE 15 m	AUTOMATIC GAIN CONTROL	WINDOW SIZE (UNITS) 80 BEFORE
HORIZONTAL SCALE		CONSTANT VALUE	80 AFTER
0 25 50 75 100 m		INITIAL GAIN	20
		MUTING	0-15 msec

85.12

85.11

84.1

85.10

85.15

WES

UPPER GLACIOLACUSTRINE
& HALTON UNITS

LOWER GLACIOLACUSTRINE UNIT

LOWER TILL

BEDROCK

OWMC Ontario
Waste Management
Corporation

Consultant:



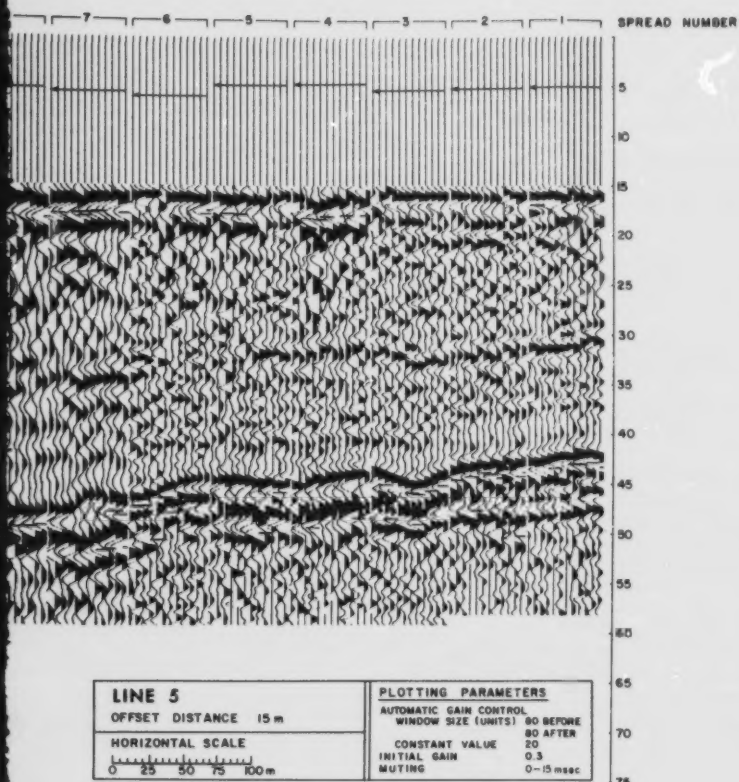
WATERLOO
GEOPHYSICS



Legend:

- ① Reflective Horizon Number 1
- ② Reflective Horizon Number 2
- ③ Reflective Horizon Number 3

85-14 Borehole Location



WEST

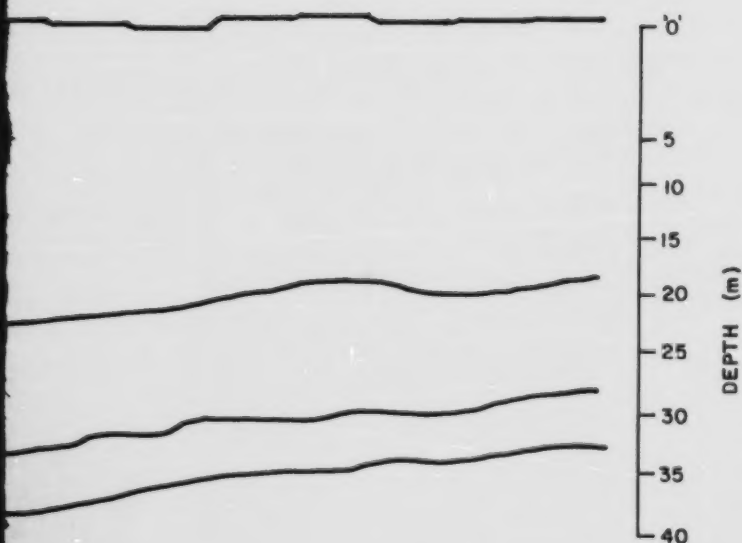
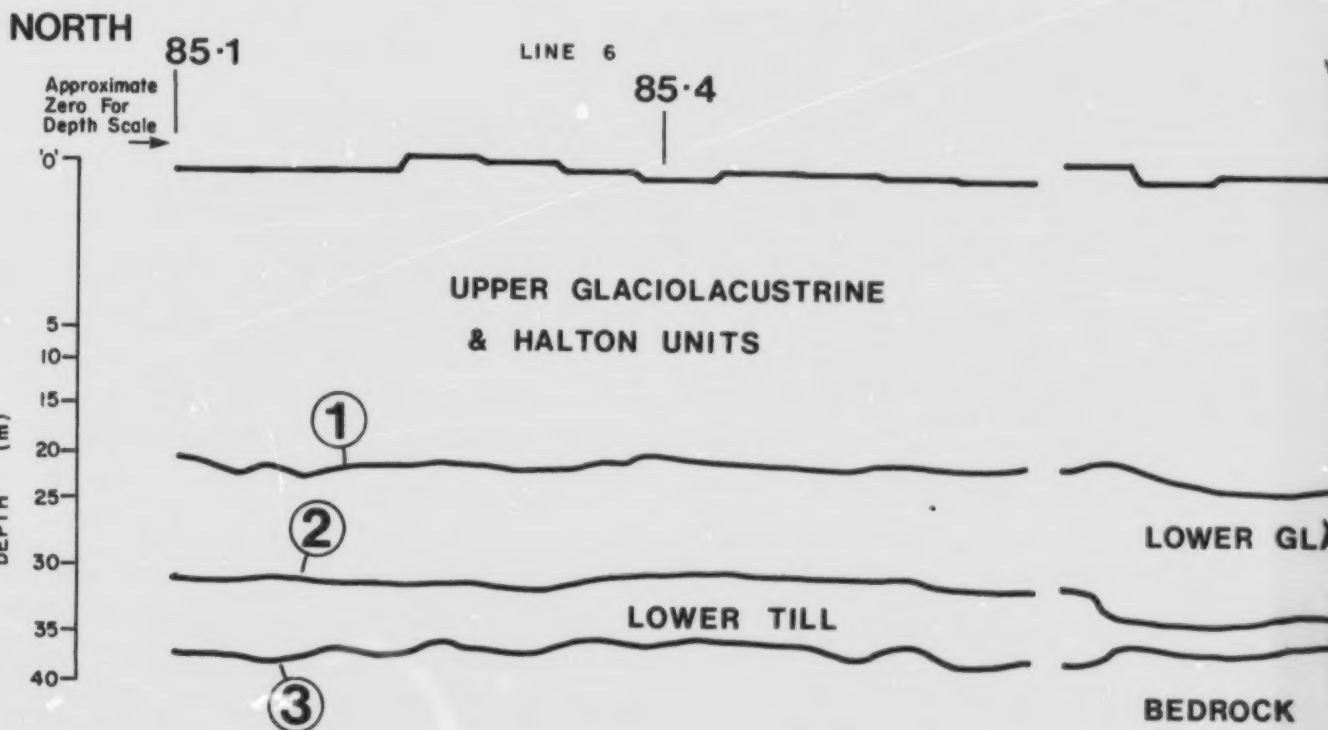
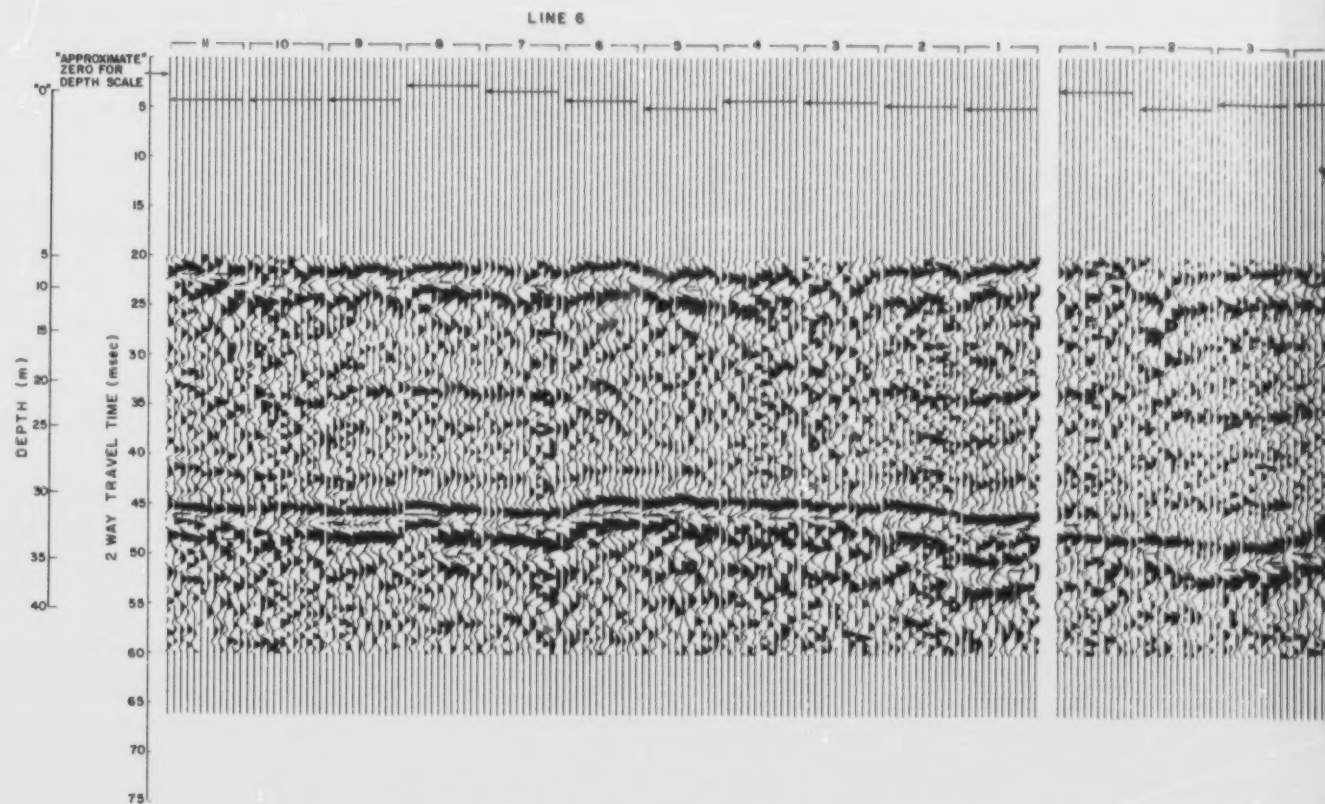


FIGURE D5-5

**Seismic
Cross-Section
Line 5**



OWMC Ontario
Waste Management
Corporation

Consultant:



Legend:

- ① Reflective Horizon Number 1
- ② Reflective Horizon Number 2
- ③ Reflective Horizon Number 3

85-14 Borehole Location

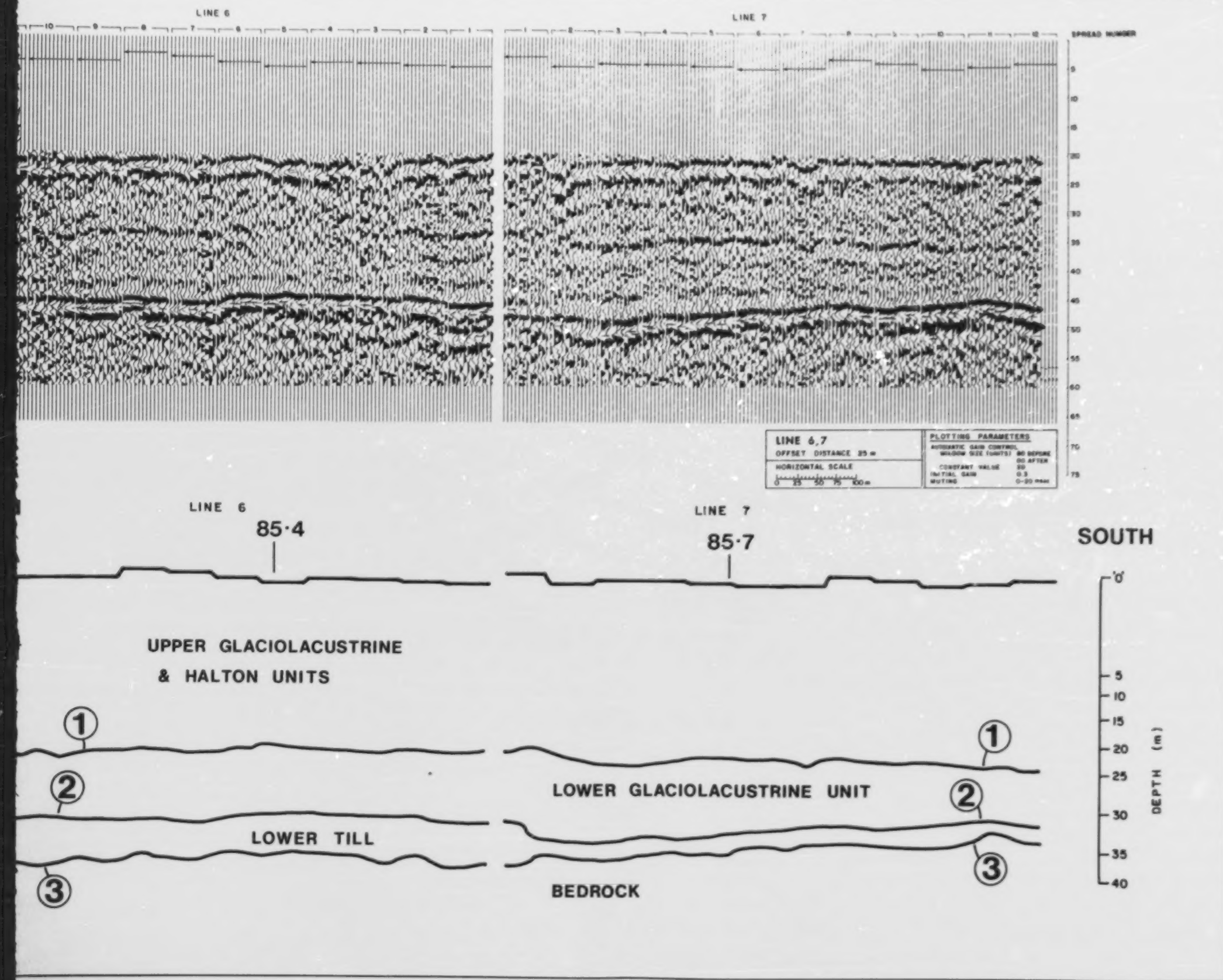
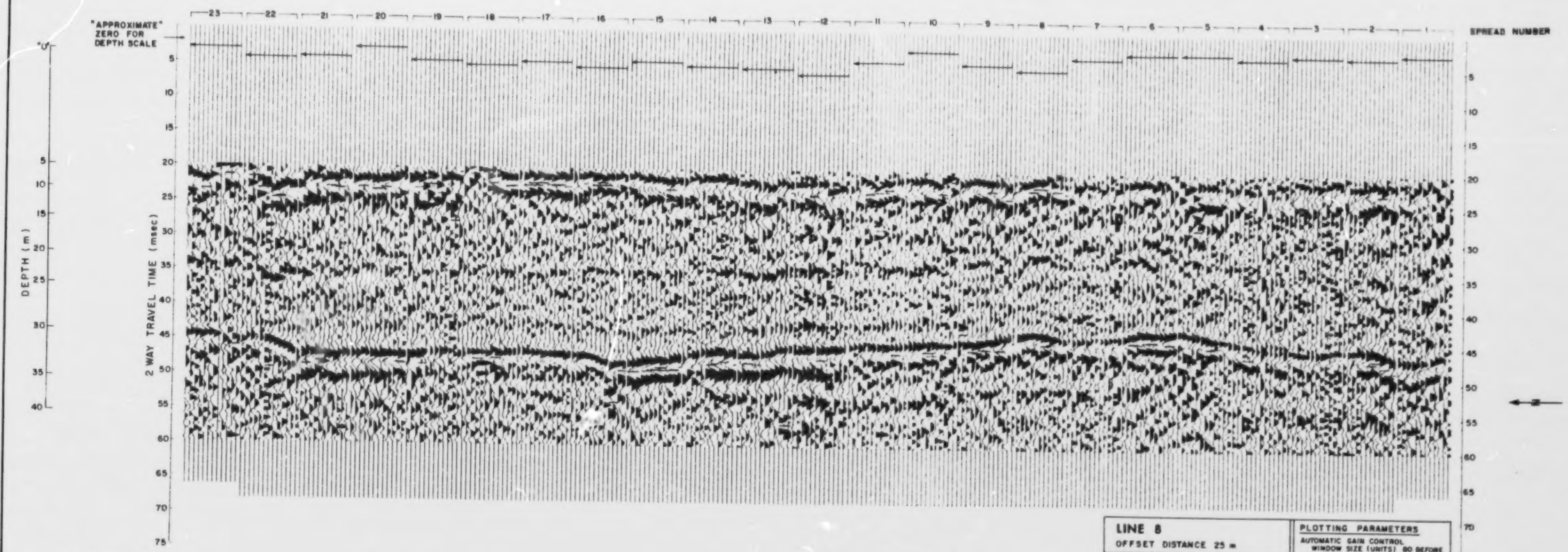
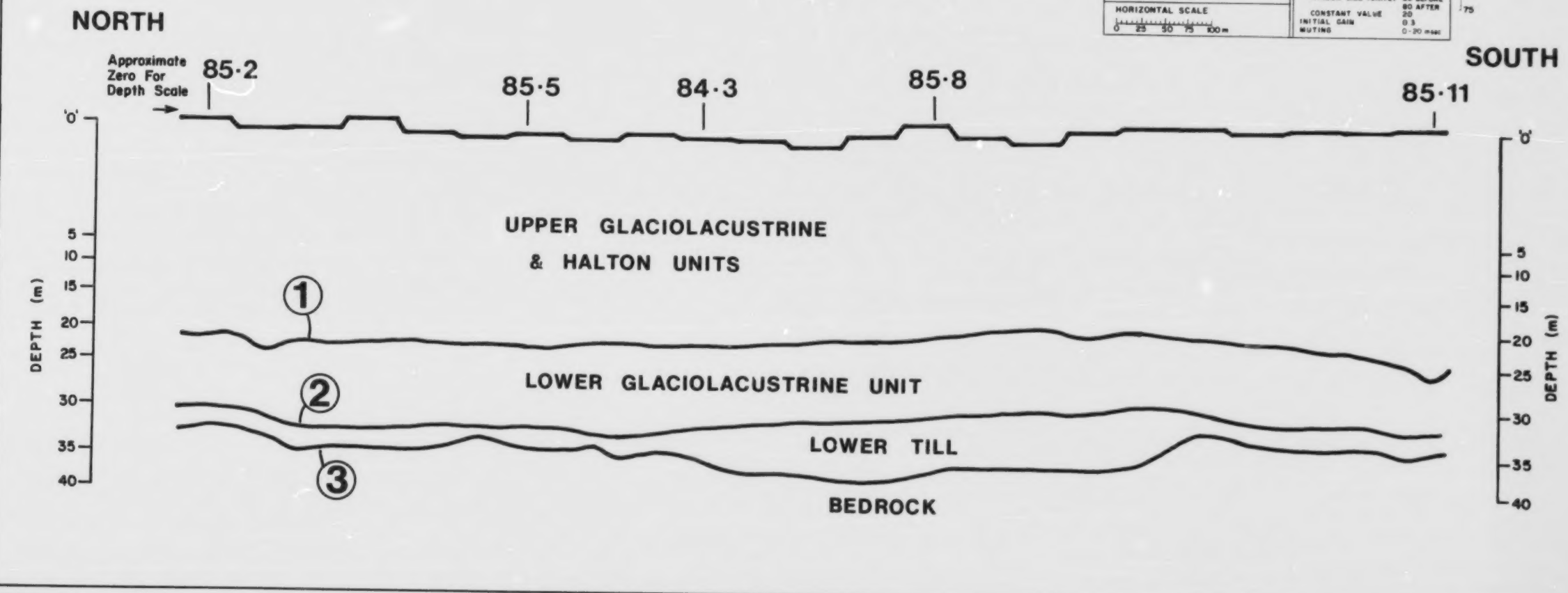


FIGURE D5-6

**Seismic
Cross-Section
Lines 6 and 7**



LINE 8		PLOTTING PARAMETERS	
OFFSET DISTANCE 25 m		AUTOMATIC GAIN CONTROL	
HORIZONTAL SCALE		WINDOW SIZE (UNITS) 80 BEFORE	
0 25 50 75 100 m		80 AFTER	
		CONSTANT VALUE 20	
		INITIAL GAIN 0.5	
		MUTING 0-20 msec	



OWMC Ontario Waste Management Corporation

Consultant:



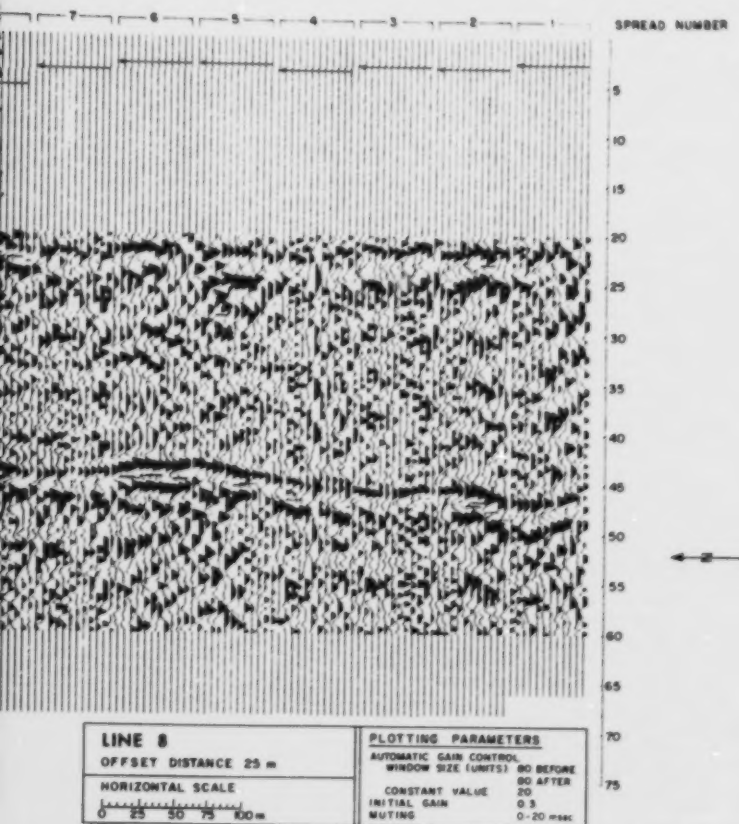
WATERLOO
GEOPHYSICS



Legend:

- ① Reflective Horizon Number 1
- ② Reflective Horizon Number 2
- ③ Reflective Horizon Number 3

85-14 Borehole Location



SOUTH

85-11

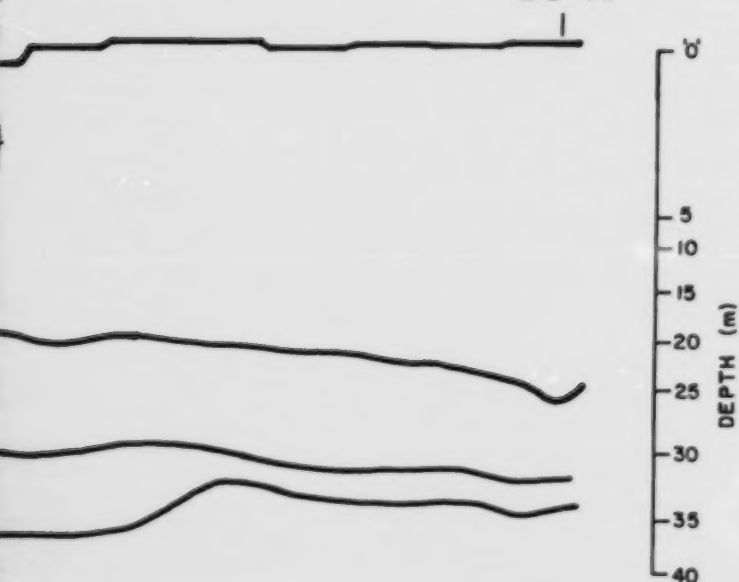


FIGURE D5-7

**Seismic
Cross-Section
Line 8**

TABLE D5-1: COMPARISON OF GEOLOGIC CONTACTS FROM BOREHOLE LOGS WITH GEOPHYSICAL CONTACT MEASUREMENTS

Borehole Numbers	1985																1984				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1	2	3	4	5
Geologic Depth to: Lower Glaciolacustrine Unit (m)	21.8	21.0	19.9	23.5	22.0	21.8	21.8	21.4	20.3	21.9	23.3	23.8	24.4	21.2	22.7	20.9	20.4	18.7	17.9	20.5	20.5
Lower Till (m)	33.0	31.5	29.9	31.3	33.9	33.6	33.3	32.0	32.9	31.5	34.2	35.3	39.1	29.2	34.4	25.4	31.6	29.3	32.5	31.1	32.6
Bedrock (m)	34.3	33.6	31.5	35.1	37.4	35.5	35.7	36.0	34.4	36.7	37.8	38.1	38.0	39.5	35.6	26.6	34.8	30.1	33.8	34.4	33.6
Geophysical Depth to: Lower Glaciolacustrine Unit (m)	20	22	20	21	22	22	21	22	20	22	23	23	23	22	23	19	22	20	20	N/A	N/A
Lower Till (m)	30	31	29	30	31	32	32	31	32	32	34	34	35	30	34	23	31	29	31	N/A	N/A
Bedrock (m)	35	33	32	35	34	34	34	37	34	37	38	38	37	38	38	26	35	31	35	N/A	N/A

sists of interbedded till and glaciolacustrine clayey silt, to the Lower Glaciolacustrine Unit consisting of well laminated clay and silt. The boundary between the Halton Unit and the Lower Glaciolacustrine Unit was also evident from laboratory testing by the increase in plasticity and decrease in unit weight. This is described in Section 6.0. This reflector is uniformly present throughout all the seismic cross-sections.

Based on the interpretation of seismic data the depth to this reflector averages 21 ± 2 m beneath the Preferred Site. Its maximum depth of 25 m was found about 420 m south of the site boundary along Heaslip Road (Line 1, Spread 16). The reflective horizon is about 18m deep at its shallowest location about 1140 m south of the site boundary along Heaslip Road (Line 1, Spread 4).

D5.1.2 REFLECTIVE HORIZON NUMBER 2

The second major reflector is extremely strong and was identified along all seismic survey lines. This reflector corresponds to the contact between the Lower Glaciolacustrine Unit, a clay and silt, and the Lower Till, a silt and sand till with locally high gravel content. The contact between the lower Glaciolacustrine and Lower Till units is characterized by a decrease in moisture content and an increase in Standard Penetration Resistance values as described in Section 6.0.

The depth to this reflector from the seismic interpretation ranges between 29 and 35 m beneath the Preferred Site. A maximum depth of 36 m was identified about 300 m south of the site boundary on Heaslip Road (Line 1, Spreads 16 and 17). Depths on the order of 35 m, were found about 440 m west of the site boundary on Vaughan Road (Line 5, Spread 9) and about

900 m east of the site boundary on Vaughan Road (Line 5, Spreads 45 and 48). The shallowest depth of about 23 to 25 m occurs about 1000 m north of the site boundary on Silverdale Road (Line 3, Spreads 16-83).

D5.1.3 REFLECTIVE HORIZON NUMBER 3

The third reflector corresponds with the contact between the lower Till and the bedrock. This reflector, though strong over most of the site, is sometimes difficult to trace because much of the seismic energy was reflected back by the overlying Lower Till.

The depth to the bedrock reflector varies from about 31 to 38 m beneath the Preferred Site with a deepening trend to the south. Bedrock is shallowest about 1150 m north of the site boundary along Silverdale Road (Line 3, Spread 15). Bedrock is deepest about 950 to 1000 m south of the site boundary along Heaslip Road (Line 1, Spreads 6, 7 and 8).

D5.2 TOTAL THICKNESS OF THE OVERBURDEN UNITS

Based on the geophysical survey results the overburden thickness across the surveyed area varies from 28 to 38 m. The thinnest overburden found 1150 m north of the site. The thickest overburden was noted about 950 to 1000 m south of the site boundary on Heaslip Road.

D5.2.1 THICKNESS OF THE CLAY AND SILT STRATA

The clay and silt strata are composed of:

- the Upper Glaciolacustrine Unit;
- the Halton Unit; and
- the Lower Glaciolacustrine Unit.

The base of the clay and silt coincides with Reflective Horizon 2. The average thickness of these strata is about 32 m beneath the Preferred Site, and ranges between 29 and 35 m. The strata thin to 23-25 m about 1000 m north of the site boundary on Silverdale Road (Line 3, Spreads 16-23 in Figure D5-3). The thickest sequence of clay and silt occurs about 300 m south of the site boundary on Heaslip Road (Line 1, Spreads 16 and 17 in Figure D5-1). The clay and silt are about 36 m thick at this location.

D5.2.2 THICKNESS OF THE LOWER TILL

The Lower Till is identified as the sequence of materials between Reflective Horizons 2 and 3. The Lower Till overlies the bedrock and is continuous within the area mapped with the seismic survey. The Lower Till usually conforms with the bedrock topography and appears to infill depressions in the rock surface. This unit varies in thickness from a typical value of 1 to 2 m to about 6 m in depressional areas on the bedrock surface. The thickest area of the Lower Till is located about 960 m south of the site boundary along Heaslip Road. The till is about 10 m thick at this location.

D6 CONCLUSIONS

The seismic interpretation correlated well with the geologic interpretation. The seismic character of the overburden below 25 to 30 msec of two way travel time is uniform. The seismic data, in combination with borehole data, suggest continuous and correlatable geologic contacts within the overburden beneath the entire study area.

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D-38

D8 - VELOCITY ANALYSIS DATA

LINE	SPREAD	REF. VEL	SURF. VEL.		DT	REFR. T	ZERO T
			1	2			
		(m/sec)	(m/sec)		(msec)	(msec)	(msec)
1	1	1629	505	481	1.8	8.5	9.61
	2	1627	656	707	2.2	8.3	10.17
	3	1582		353	2	8.5	9.38
	4	1633	404	326	1.8	8.8	9.62
	5	1598		640	2.6	8.4	10.48
	6	1608	533	365	3.2	8.3	10.10
	7	1596	423		1.7	8.9	9.80
	8	1585			2.2	8.6	9.57
	9	1625	416	382	2.6	8.4	9.70
	10				2.5		
	11	1571	414	431	2.4	8.7	9.97
	12	1584	352	435	3.2	8.3	9.87
	13	1661	611		1.9	8.4	9.85
	14	1640	400	403	1.6	8.6	9.40
	15	1612	379	320	2.7	8	9.18
	16	1605	783	780	1.5	8.6	10.07
	17	1649		833	1.9	8.2	10.18
	18	1670	437		1.9	8.2	9.24
	19	1638	583	718	2.2	8.2	9.99
	20	1642	577	642	2.2	8.2	9.88
	21	1643	406	610	2.8	7.6	9.38
	22	1622		512	2.6	7.9	9.56
2	1	1616	753	672	3.7	13.5	16.80
	2	1597	677	814	3.3	13.8	16.88
	3	1592	570	866	2.2	14.5	16.47
	4	1613	598	687	4.2	13.4	16.77
	5	1527	548	621	4	14.1	17.02
	6	1570	522	515	3.6	14.5	16.83
	7	1580	515	377	4.1	14.2	16.49
	8	1510	522		3.8	14.9	17.38
	9	1545		426	3.3	14.5	16.26
	10	1534	874	638	2.9	14.8	17.54
	11	1537	514	588	3.8	14.3	16.92
	12	1525	559	566	3.4	14.8	17.19
	13	1592	580	566	3.6	14.8	17.38
	14	1581	522	696	1.9	14.9	16.35
	15	1572	509	828	2.8	14.4	16.74
	16	1604	424	707	2.6	14.3	16.14
	17	1636	979	456	2.9	14	16.60
	18	1574	458	559	1.2	15.3	16.06
	19	1595	448	863	1.9	14.8	16.36
	20	1770			3.4	12.8	12.80
	21	1536	488	426	3	14.8	16.51
	22						
	23						
3	1	1609			1.9	14.8	14.80
	2	1580	546	530	2	15.1	16.45

LINE	SPREAD	REF. VEL	SURF. VEL.		DT	REFR. T	ZERO T
		(m/sec)	1	2	(msec)	(msec)	(msec)
			(m/sec)	(m/sec)			
3	3	1551	450	500	2.8	15	16.66
	4	1614	353	437	2.8	14.1	15.48
	5	1550	723	777	1.9	15.1	16.88
	6	1523	706	583	2	15.3	16.91
	7	1650	706		1.7	14.6	16.10
	8	1612	569	300	2.4	14.8	16.10
	9	1590	443	533	2.2	15	16.34
	10	1601	538	480	2	14.8	16.07
	11	1583	557	495	2.3	14.9	16.41
	12	1596	423	477	1.8	15	16.01
	13	1578	396	498	2.1	15	16.17
	14	1605	474		0.4	15.4	15.64
	15	1701	725	640	0.3	14.6	14.86
	16	1558	492	832	2.1	8.5	10.24
	17	1613	634	596	1.4	8.6	9.68
	18	1588	985	897	1.8	8.4	10.52
	19	1552	584	913	2	8.5	10.37
	20	1630	380	404	1.6	8.6	9.38
	21	1609	336	565	2	8.6	9.73
	22	1628	522		1.8	8.6	9.77
	23	1595	393		1.7	8.8	9.64
4	1	1578	897		1.1	15.1	16.33
	2	1627	760		2	14.1	16.00
	3	1576	1077	1077	1.5	14.8	16.82
	4	1614	529	862	1	15	15.87
	5	1631	415	706	2.1	14.3	15.77
	6	1640		517	2	14.2	15.49
	7	1547		664	1.3	15.4	16.48
	8	1609	747	840	1.8	14.5	16.29
	9	1611	745	583	1.6	14.6	15.93
	10	1610			2.5	14.1	15.80
	11	1624	756	307	1.4	14.5	15.43
	12	1577	348	423	1.2	15.4	15.98
	13	1543	554	647	3.6	15	17.70
	14	1526		470	4.8	13.4	16.22
	15	1573	760	745	4.4	13.4	17.54
	16	1634	657	815	2.1	14.2	16.13
5	1	1605	718	1166	1.7	8.2	10.20
	2	1572	467	1118	0.8	9	9.79
	3	1563	731	931	1.7	8.6	10.37
	4	1530	745		2.4	8.3	10.54
	5	1605	621		1.3	8.6	9.61
	6	1600	616	725	1.4	8.6	9.77
	7	1642	530	1118	2.6	7.5	10.18
	8	1565	1166	675	2.1	8.2	10.62
	9	1599		566	1.9	8.2	9.54
	10	1589	897	499	2.2	8.3	10.22

LINE	SPREAD	REF. VEL (m/sec)	SURF. VEL.		DT (msec)	REFR. T (msec)	ZERO T (msec)
			1 (m/sec)	2 (m/sec)			
6	9	1551	1188	913	4.2	13.1	18.62
	10	1553		479	3.5	13.6	14.65
	11	1557			2.9	14	14.60
7	1	1754	529	1096	4	12.5	16.56
	2	1661	609	614	4.1	13	16.13
	3	1673	538	596	4.4	12.7	15.82
	4	1680	529	614	4.7	13	16.36
	5	1692	559	566	3.3	13.5	15.82
	6	1659	500	348	3.4	13.7	15.50
	7	1560	614	687	4.1	14.4	17.73
	8	1600			4.8	14.3	16.80
	9	1643		541	3	14	16.03
	10	1610	448	512	3.1	14.3	16.16
	11	1695	523	512	2.8	13.5	15.31
	12	1589	672			14	14.00
8	1	1626	416	671	4.8	14.9	18.16
	2	1559	657	634	5.4	13.7	18.06
	3	1581			5.3	14.6	14.60
	4	1694		645	5.5	14	18.43
	5	1682	598			14	14.00
	6	1718	656	582	3.8	14.5	17.44
	7	1716	718	609	4.2	13.7	17.18
	8	1653	731	466	3.4	13.5	16.04
	9	1674	636	819	3.6	13	16.27
	10	1559		1044	3.9	13.1	18.19
	11	1506	1177	596	3.5	13	16.88
	12	1638		1059	4.1	12.5	15.21
	13	1701	792	706	3.6	12.6	15.97
	14	1654	706	656	3.6	12.5	15.56
	15	1625	1096		3	12.4	16.51
	16	1545	745	598	2.3	12.7	14.63
	17	1560	798	728	3.3	12.8	15.95
	18	1580	583	1019	3.2	12.4	15.60
	19	1624	599		4	12.9	15.90
	20	1619	978	642	4	14	18.05
	21	1592	891	685	3.5	13	16.45
	22	1585		728	3.5	13.6	16.79
	23	1630				14	16.80

Volume

3

Final report

OWMC

**Ontario
Waste Management
Corporation**

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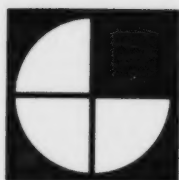
SITE ASSESSMENT
PHASE 4B:
GEOLOGY, HYDROGEOLOGY AND
GEOTECHNICS, BASELINE CONDITIONS
VOLUME 3
APPENDICES E THROUGH J

Prepared for
The Ontario Waste Management Corporation

Submitted By

Gartner Lee Limited

October, 1987



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October 30, 1987

GLL 87561

Mr. J.G. Micak
Manager, Environmental Projects
Ontario Waste Management Corporation
2 Bloor Street West, 11th Floor
Toronto, Ontario
M4W 3E2

Attention: Mr. D.F. Chollak,
Environmental Planner

Dear Sirs:

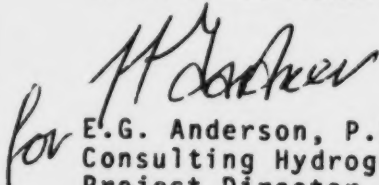
Re: Site Assessment Phase 4B: Geology,
Hydrogeology and Geotechnics
- Baseline Conditions

We are pleased to provide you with Volume 3 of the above noted three-volume report. This report is one of six Phase 4B companion reports describing baseline conditions, hydrogeologic inputs to landfill design, geotechnical inputs to facilities design, potential impacts of the landfill on ground water, potential impacts of the central operation area on ground water and ground water management strategies.

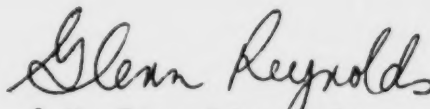
We thank you for this opportunity to be of service. Should you have any questions please do not hesitate to call.

Yours very truly,

GARTNER LEE LIMITED

for 
E.G. Anderson, P.Eng.
Consulting Hydrogeologist
Project Director

GWR:emh


G.W. Reynolds, M.Sc.,
Senior Hydrogeologist,
Project Manager



- E-1 -

APPENDIX E

GEOTECHNICAL INFORMATION

APPENDIX E
GEOTECHNICAL INFORMATION

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E1 - LABORATORY TEST RESULTS

GOLDER ASSOCIATES (EASTERN CANADA) LTD. REPORT

REFERENCE NO. 851-1298

Appendix E1 contains, in full, the factual report prepared by Golder Associates (Eastern Canada) Ltd. on the geotechnical laboratory testing carried out on samples obtained from the geotechnical boreholes.

These tests included;

- WATER CONTENT DETERMINATIONS
(ASTM D2216-80)
- INDEX PROPERTIES
(ASTM D2216-80, D4318-84, D422-63)
- LABORATORY VANE SHEAR TESTS
- UNDRAINED TRIAXIAL TESTS
(ASTM D2850-82)
- UNCONFINED, UNDRAINED TRIAXIAL COMPRESSION TESTS
(ASTM D2166-85)
- CONSOLIDATED, UNDRAINED TRIAXIAL TESTS
(Bishop & Henkel Method)
- DIRECT SHEAR TESTS
(ASTM D3080-72-modified)
- CONSOLIDATION TESTS
(ASTM D2435-80)
- COMPACTION TESTS
(ASTM D698-78)



Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

FACTUAL REPORT TO
GARTNER LEE ASSOCIATES LIMITED

CONFIDENTIAL

LABORATORY TESTING OF CLAY SOILS
ONTARIO WASTE MANAGEMENT
CORPORATION
4B PROGRAM

Gartner Lee Associates Ref. 85-GT-4

DISTRIBUTION:

2 copies, bound	-	Gartner Lee Associates Limited
1 copy , unbound		Markham, Ontario
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		Mississauga, Ontario

May, 1986

851-1298

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May 9, 1986

Our ref: 851-1298

Gartner Lee Associates Limited
Toronto-Buttonville Airport
Markham, Ontario
L3P 3J9

ATTENTION: Mr. R. D. Powell, P. Eng.

RE: LABORATORY TESTING OF CLAY SOILS
ONTARIO WASTE MANAGEMENT CORPORATION
4B PROGRAM
GLAL REF: 85-GT-4

Dear Sirs:

This letter reports the factual results of laboratory tests carried out on samples of clay soils delivered to our laboratory by Gartner Lee Associates Limited. We understand that the samples were obtained from various sites within the OWMC 4B Program.

LABORATORY TESTING

The laboratory tests were carried out in our geotechnical laboratory in Mississauga, Ontario, using the testing program as specified by Gartner Lee Associates Limited. The tests were carried out in accordance with the current ASTM standards, where applicable, as noted in the following sections of the report; any variations from the standards are described. Due to the volume of testing and the time required to complete the scheduled work, the test results were submitted to Gartner Lee Associates in a preliminary form as they became available.

All test results within this report are deemed to be confidential as per the Undertaking of Confidentiality Agreement with the Ontario Waste Management Corporation.

TEST SAMPLES

During the period from December 6, 1985 to March 14, 1986, our laboratory received samples for testing from Gartner Lee Associates. These samples were delivered in sealed plastic containers or 2.78 in. diameter Shelby tubes which were waxed and capped. The Shelby tube samples were stored, horizontally, in our concrete curing room until required for testing. Samples received in plastic containers were used for water content determinations on the date received.

At the time of delivery, Chain of Custody documents were signed and exchanged by both parties.

WATER CONTENT DETERMINATIONS (ASTM D2216-80)

Water content determinations were carried out on clay soil samples that were delivered to our laboratory. These tests were carried out using the whole sample (approximately 70 gm dry weight) on the day of receipt. The results of the water content determinations are summarized on Tables 1 to 6, inclusive.

INDEX PROPERTIES (ASTM D2216-80, D4318-84, D422-63)

The portion of each sample extruded from the Shelby tubes for testing was visually examined to observe the undisturbed fabric of the material to provide a laboratory description of soil type. The trimmings from the test samples were used for the index tests which comprised water content determinations,

Atterberg Limits and grain size analyses. These tests were carried out in accordance with ASTM designations D2216-80, D4318-84 and D422-63, respectively. Plots of the grain size distributions are given on Figures 48 to 75, inclusive. Due to computer limitations, the boreholes on the grain size plots were designated by site and hole number only.

LABORATORY VANE SHEAR TESTS

Laboratory vane shear tests were carried out on samples within the Shelby tubes. As discussed prior to carrying out these tests, the samples were cut such that the tests could be conducted on planes oriented at 0° , 38° and 90° to the horizontal (note: the longitudinal axis of the samples is oriented at 90° to the horizontal). These tests were carried out using a 'Geonor' laboratory vane apparatus with a vane length of one half inch. Table 7 summarizes the peak and residual undrained shear strengths obtained from the vane tests, along with the water content at the point of testing. Reference to "base" and "top" under the remarks column indicates tests made at each end of the angled section relative to the base of the Shelby tube.

UNDRAINED TRIAXIAL TESTS (ASTM D2850-82)

Unconsolidated, undrained triaxial compression tests were carried out on specified samples using the effective overburden pressure as the confining pressure. These samples were trimmed at 90° to the horizontal with a nominal 2:1 length/diameter ratio. The results of these tests are shown on Figures 1-1 to 11-2, inclusive.

UNCONFINED, UNDRAINED TRIAXIAL COMPRESSION TESTS
(ASTM D2166-85)

Unconfined, undrained triaxial compression tests were carried out on samples at different angles of orientation. Samples with a nominal 2:1 length/diameter ratio were trimmed at angles of 90° , 45° and 0° to the horizontal plane. The results of these tests are shown on Figures 12-1 to 30-2, inclusive.

CONSOLIDATED, UNDRAINED TRIAXIAL TESTS
(Bishop & Henkel Method)

Consolidated, undrained triaxial tests with pore water pressure measurements at specified effective cell pressures were carried out. Due to the time required for equalization of the pore pressures, a nominal strain rate of 0.5 percent per hour was selected. However, the time to failure exceeded normal working hours; therefore, the tests were either stopped overnight or slowed down to a strain rate of 0.25 percent per hour. The notations shown on the deviator stress vs axial strain plot for each test summarizes the strain rate history of the tests. The results of the testing are shown on Figures 31-1 to 33-3, inclusive. The computer data sheets for this testing are given in Appendix 1.

DIRECT SHEAR TESTS (ASTM D3080-72-modified)

Consolidated, drained direct shear tests were carried out on samples that were trimmed so that the shear plane was established at 0° to the horizontal plane. The direct shear test on Sample 6 from BH 85-3-2 was carried out as a peak strength test only, stopping the strain rate overnight. All of the remaining direct shear tests were carried out as peak and residual strength tests, with the sequence given below.

Using a strain rate of 0.5 percent per hour to allow total drainage across the shear plane, the tests were allowed to travel the maximum distance of the shear box. Using the hand crank, the shear plane was returned to the original position. Five additional forward and reverse passes were then made over a total time period of approximately one half hour. The sample was then allowed to stand for two hours, allowing the pore water pressures to dissipate. The final run, noted as the sixth pass, was then made using the previous strain rate of 0.5 percent per hour.

The results of these tests are shown on Figures 34-1 to 39-3, inclusive, with the strain rate history being shown on the shear stress vs horizontal displacement plots. The residual points on the shear stress vs normal stress plot refer to the sixth pass of the test. Computer data sheets for the direct shear tests are given in Appendix 2.

CONSOLIDATION TESTS (ASTM D2435-80)

Consolidation tests were carried out using fixed ring, Bishop bench type presses with samples of 63.5 mm diameter and 19.05 mm height. The standard load increments were applied every 24 hours up to the consolidation press maximum, then rebounded to the original load or swelling pressure, where applicable. The results of these tests are shown on Figures 40-1 to 45-2, inclusive.

COMPACTION TESTS (ASTM D698-78)

Two standard Proctor compaction tests, using composite materials from specific areas, were carried out. The results of these tests are shown on Figures 46 and 47.

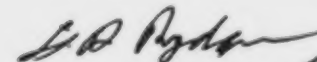
May, 1986

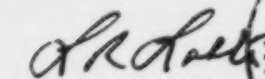
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We trust that this report is adequate for your purposes.
If there are any questions regarding this report, please
contact us.

Yours truly
GOLDER ASSOCIATES


F. A. Rydgren


Leo R. Lahti,
FAR/LRL/jm



May, 1986

851-1298

WATER CONTENT DETERMINATIONS

TABLES 1 to 6

TABLE 1

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
DATE TESTED December 9, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
			W-2	36.9%
			W-3	19.3%
			W-6	16.8%
			W-8	22.7%
			W-14	21.2%
			W-15	21.4%
			W-17	25.6%
			W-18	21.6%
			W-23	29.0%
			W-232	24.9%
			W-25	19.2%
			W-26	20.3%
			W-27	20.0%
			W-28	17.6%
			W-30	23.9%
			W-31	25.3%
			W-39	24.6%
			W-40	23.1%
			W-41	28.9%
			W-47	35.5%
			W-48	20.3%
			W-49	21.1%
			W-50	22.4%

TABLE 1

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
DATE TESTED December 9, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
			W-51	30.6%
			W-53	12.6%
			W-55	27.6%
			W-57	5.8%
			W-62	29.3%
			W-70	22.3%
			W-72	6.8%
			W-82	31.1%
			W-84	23.0%
			W-92	29.9%
			W-126	29.1%
			W-129	22.0%
			W-135	27.4%
			W-138	36.1%
			W-151	19.6%
			W-153	37.4%
			W-203	29.3%
			W-204	18.0%
			W-205	22.7%
			W-206	17.5%
			W-207	21.1%
			W-208	17.1%
			W-209	18.1%

TABLE 1

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED December 9, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
			W-210	20.7%
			W-211	22.7%
			W-212	20.0%
			W-213	17.9%
			W-214	14.0%
			W-216	31.0%
			W-217	16.1%
			W-230	21.9%
			W-231	23.2%
			W-234	22.3%
			W-239	25.6%
			W-243	22.7%
			W-245	23.6%
			W-259	22.8%
			W-264	31.2%
			W-268	4.5%
			W-272	18.7%
			W-273	17.6%
			W-274	27.0%
			W-280	18.7%
			W-281	23.3%
			W-286	39.5%
			W-289	26.5%

TABLE 1

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
DATE TESTED December 9, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
			W-292	17.8%
			W-295	27.0%
			W-310	30.4%
			W-314	22.0%
			W-324	20.2%
			W-332	21.4%
			W-358	24.8%

TABLE 2

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/OWMC 4B/85-GT-4
 DATE TESTED December 20, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-3-2		1.20	W-9	25.6
85-3-2		2.00	W-37	23.7
85-3-2		2.70	W-294	21.3
85-3-2		3.50	W-279	19.8
85-3-2		4.30	W-98	22.6
85-3-2		8.10	W-251	17.9
85-3-2		9.60	W-328	19.4
85-3-2		14.20	W-252	22.5
85-3-2		15.70	W-285	20.3
85-3-2		17.20	W-302	23.1
85-3-2		20.30	W-43	39.1
85-3-2		21.80	W-308	29.4
85-3-2		23.30	W-44	41.3
85-3-2		27.90	W-242	35.9
85-3-2		29.40	W-121	38.1
85-3-2		26.50	W-236	34.9
85-3-2		27.10	W-258	28.3
85-3-4		15.80	W-278	21.3
85-3-4		16.4	W-311	22.9
85-3-5		1.52	W-296	28.0
85-3-5		2.13	W-287	25.3
85-3-5		2.74	W-336	24.0
85-3-5		3.35	W-315	19.8

TABLE 2

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 48/85-GT-4
 DATE TESTED December 20, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-3-5		3.96	W-260	24.0
85-3-5		4.60	W-290	29.5
85-3-5		5.18	W-344	29.0
85-3-5		5.84	W-269	23.1
85-3-6		27.43	W-241	30.3
85-3-7		16.44	W-257	20.3
85-5-2		1.22	W-131	23.2
85-5-2		1.98	W-127	24.1
85-5-2		2.74	W-60	27.0
85-5-2		3.51	W-71	19.1
85-5-2		4.28	W-233	24.2
85-5-2		5.35	W-130	28.4
85-5-2		6.55	W-67	28.4
85-5-2		8.08	W-226	18.0
85-5-2		9.76	W-200	19.2
85-5-2		11.13	W-58	18.8
85-5-2		12.65	W-201	20.6
85-5-2		14.17	W-33	21.2
85-5-2		15.70	W-120	24.4
85-5-2		17.22	W-225	22.7
85-5-2		18.74	W-74	24.8
85-5-2		20.27	W-73	29.6
85-5-2		21.79	W-65	23.8

TABLE 2

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED December 20, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-5-2		23.32	W-45	28.1
85-5-2		24.84	W-56	27.8
85-5-2		26.37	W-32	22.2
85-5-2		27.89	W-229	27.8
85-5-2		29.41	W-228	26.5
85-5-2		30.94	W-215	38.2
85-5-2		32.46	W-154	30.6
85-5-2		33.99	W-52	36.6
85-5-2		35.51	W-64	6.5
85-5-3		26.36	W-282	37.0
85-5-3		26.83	W-338	29.2
85-9-2		1.20	W-297	25.9
85-9-2		2.00	W-249	24.7
85-9-2		2.70	W-10	21.8
85-9-2		3.50	W-13	19.8
85-9-2		4.30	W-342	27.4
85-9-2		5.00	W-244	24.7
85-9-2		6.60	W-38	33.4
85-9-2		8.10	W-316	24.9
85-9-2		9.60	W-343	17.0
85-9-2		11.10	W-22	21.9
85-9-2		12.60	W-304	19.9
85-9-2		14.20	W-12	18.0

TABLE 2

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED December 20, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-9-2		15.70	W-317	24.0
85-9-2		17.20	W-281	23.7
85-9-2		18.70	W-237	23.2
85-9-2		20.30	W-16	27.8
85-9-2		21.40	W-77	31.9
85-9-2		23.30	W-276	31.5
85-9-2		24.80	W-275	30.4
85-9-2		25.90	W-54	27.7
85-9-2		27.00	W-292	26.7
85-9-2		29.40	W-240	25.8
85-9-2		31.50	W-277	29.2
85-9-2		32.50	W-266	39.2
85-9-2		33.70	W-11	14.2
85-9-3		26.50	W-352	29.7
85-9-3		27.10	W-29	25.5
85-9-4		15.85	W-80	26.0
85-9-4		16.46	W-24	24.5
85-9-5		1.52	W-270	25.4
85-9-5		2.13	W-364	21.6
85-9-5		2.74	W-299	28.4
85-9-5		3.35	W-347	18.1
85-9-5		3.96	W-351	20.4
85-9-5		4.57	W-301	24.0

TABLE 2

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/B5-GT-4
 DATE TESTED December 20, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-9-5		5.18	W-349	30.6
85-9-5		5.79	W-283	33.6
85-10-2		1.20	W-359	22.4
85-10-2		2.00	W-263	21.5
85-10-2		2.70	W-305	19.4
85-10-2-		3.50	W-353	22.7
85-10-2		6.50	W-348	22.9
85-10-2		8.10	W-366	27.0
85-10-2		9.60	W-298	26.0
85-10-2		10.60	W-288	19.8
85-10-2		12.60	W-34	26.4
85-10-2		14.20	W-333	19.8
85-10-2		15.70	W-325	20.1
85-10-2		16.70	W-1	22.9
85-10-2		18.70	W-7	20.2
85-10-2		20.30	W-322	18.3
85-10-2		21.30	W-340	18.5
85-10-2		23.30	W-339	35.5
85-10-2		24.80	W-267	36.6
85-10-2		25.80	W-309	28.6
85-10-2		27.90	W-376	35.7
85-10-2		29.40	W-319	39.4
85-10-2		30.40	W-375	39.4

TABLE 2

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
DATE TESTED December 20, 1985

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-10-2		32.50	W-291	7.3
			W-255	25.9

TABLE 3

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 48/85-GT-4
 DATE TESTED January 10, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-3-8	5	25.10	W-354	26.9
85-3-9	1	16.00	W-238	22.1
85-5-4	1	17.22	W-99	20.7
85-5-4	2	17.68	W-91	21.9
85-5-5	1	1.52	W-136	23.1
85-5-5	2	2.13	W-125	25.2
85-5-5	3	2.74	W-177	26.2
85-5-5	4	3.35	W-134	24.0
85-5-5	5	3.96	W-178	26.4
85-5-5	6	4.57	W-156	30.3
85-5-5	7	5.18	W-114	24.9
85-5-5	8	5.79	W-89	25.6
85-8-2	1	.76-1.22	W-36	25.4
85-8-2	2	1.52-1.98	W-112	23.2
85-8-2	3	2.29-2.74	W-96	20.6
85-8-2	5	3.81-4.28	W-148	25.6
85-8-2	6	4.57-5.03	W-165	27.0
85-8-2	7	5.11-5.57	W-144	21.9
85-8-2	9	7.82-8.08	W-111	19.5
85-8-2	10	9.14-9.60	W-158	19.3
85-8-2	11	10.67-11.	W-176	19.5
85-8-2	13	12.19-12.	W-105	23.9
85-8-2	14	13.71-14.	W-101	33.4

TABLE 3

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/QWMC 4B/85-GT-4
 DATE TESTED January 10, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-8-2	15	15.24-15.	W-128	29.9
85-8-2	16	16.76-17.	W-146	24.6
85-8-2	18	18.29-18.	W-113	24.9
85-8-2	19	19.81-20.	W-199	23.9
85-8-2	20	21.53-21.	W-174	34.4
85-8-2	21	22.86-23.	W-171	29.6
85-10-3	1	26.50	W-254	29.1
85-10-3	2	27.10	W-219	31.7
85-10-4	1	15.85	W-122	26.0
85-10-4	2	16.46	W-162	26.1
85-10-5	1	1.52	W-90	25.5
85-10-5	2	2.13	W-76	21.5
85-10-5	3	2.74	W-150	24.2
85-10-5	4	3.35	W-61	25.3
85-10-5	5	3.96	W-123	23.0
85-10-5	6	4.57	W-103	21.8
85-10-5	7	5.18	W-86	23.0
85-10-5	8	5.79	W-152	25.1
85-10-8	5	25.15	W-42	35.2
85-10-9	1	16.00	W-133	21.7
85-10-11	1	8.53-9.14	W-68	27.6
85-10-11	2	9.14-9.75	W-157	21.9
			W-132	33.1

TABLE 4

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED January 23, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-1-6		27.13	W235	29.8
85-4-2		1.20	W256	21.2
85-4-2		2.00	W248	N/A
85-4-2		2.70	W250	18.2
85-4-2		3.50	W253	18.6
85-4-2		4.30	W313	17.6
85-4-2		5.00	W355	27.8
85-4-2		5.80	W5	18.0
85-4-2		6.60	W330	18.2
85-4-2		7.30	W78	17.3
85-4-2		8.10	W81	19.0
85-4-2		9.60	W300	22.5
85-4-2		11.10	W246	22.6
85-4-2		12.6	W318	27.7
85-4-2		14.2	W4	24.4
85-4-2		15.7	W262	21.6
85-4-2		17.2	W200	23.2
85-4-2		19.7	W201	19.0
85-4-2		21.8	W118	23.7
85-4-2		23.3	W141	N/A
85-4-2		24.8	W205	25.8
85-4-2		27.9	W192	24.1
85-4-2		29.4	W115	30.0

TABLE 4

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4,
 DATE TESTED January 23, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-4-2		31	W88	31.9
85-4-2		32.5	W143	8.1
85-4-2		33.4	W202	7.2
85-4-3		26.5	W194	20.9
85-4-3		27.1	W175	24.3
85-4-4		15.8	W137	19.9
85-4-4		16.4	W186	17.3
85-4-5		1.50	W223	21.8
85-4-5		2.10	W20	18.2
85-4-5		2.70	W307	22.8
85-4-5		3.40	W202	26.3
85-4-5		4.00	W79	27.6
85-4-5		4.10	W160	25.1
85-4-5		5.2	W372	17.9
85-4-5		5.80	W334	17.4
85-7-2		1.20	W107	20.7
85-7-2		2.00	W106	20.0
85-7-2		2.70	W3	20.0
85-7-2		3.50	W35	23.1
85-7-2		5.00	W116	18.6
85-7-2		6.60	W337	17.5
85-7-2		7.70	W161	20.1
85-7-2		9.60	W385	20.4

TABLE 4

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED January 23, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-7-2		11.10	W386	19.5
85-7-2		12.60	W117	19.9
85-7-2		14.20	W85	21.4
85-7-2		15.70	W356	22.0
85-7-2		17.20	W395	27.3
85-7-2		18.30	W384	24.9
85-7-2		20.30	W224	24.6
85-7-2		21.80	W327	23.3
85-7-2		23.30	W405	21.4
85-7-2		24.80	W390	31.5
85-7-2		25.90	W63	26.4
85-7-2		27.90	W392	25.0
85-7-2		29.40	W399	31.3
85-7-2		30.90	W398	37.7
85-7-2		31.50	W403	36.0
85-7-2		33.80	W400	5.3
85-7-3		26.52	W379	28.1
85-7-4		15.35	W404	21.4
85-7-4		16.46	W391	24.9
85-7-5		1.52	W360	17.8
85-7-5		2.13	W350	18.4
85-7-5		2.74	W362	23.6

TABLE 4

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED January 23, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-7-5		3.35	W371	28.4
85-7-5		3.96	W382	32.3
85-7-5		4.57	W321	29.2
85-7-5		5.18	W409	21.2
85-7-5		5.79	W139	21.4
85-8-2		24.80	W169	32.0
85-8-2		26.40	W187	34.4
85-8-2		27.90	W197	26.2
85-8-2		29.40	W173	31.0
85-8-2		30.90	W179	27.4
85-8-2		32.50	W191	7.3
85-8-2		33.50	W196	6.6
85-8-3		26.50	W204	34.7
85-8-3		27.10	W190	28.4
85-8-4		15.90	W193	27.0
85-8-4		16.50	W181	26.8
85-8-5		1.50	W183	20.6
85-8-5		2.10	W180	27.5
85-8-5		2.70	W170	18.8
85-8-5		3.40	W184	19.5
85-8-5		4.00	W207	20.2
85-8-5		4.60	W195	26.8
85-8-5		5.20	W195	20.4

TABLE 4

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/OWMC 48/85-GT-4
 DATE TESTED January 23, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-8-5		5.80	W198	21.9
85-8-6		25.90	W166	25.5
85-8-7		16.80	W145	24.2
85-8-8		25.20	W206	24.1
85-8-9		16.10	W189	28.2
85-8-11		9.10	W182	17.8
85-8-11		10.00	W167	17.5
85-11-2		1.20	W59	22.9
85-11-2		2.00	W303	23.9
85-11-2		2.70	W220	18.7
85-11-2		3.50	W367	23.4
85-11-2		4.30	W87	24.4
85-11-2		5.00	W369	30.6
85-11-2		6.60	W75	20.5
85-11-2		8.10	W83	21.1
85-11-2		9.60	W46	20.9
85-11-2		11.10	W368	20.7
85-11-2		12.40	W377	20.6
85-11-2		14.20	W374	20.4
85-11-2		15.70	W94	18.1
85-11-2		17.20	W221	24.9
85-11-2		18.70	W293	24.4
85-11-2		21.80	W345	23.9

GOLDER ASSOCIATES

TABLE 4

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
DATE TESTED January 23, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-11-2		23.30	W284	21.3
85-11-2		24.80	W396	35.1
85-11-2		27.90	W95	24.5
85-11-2		29.40	W377	32.7
85-11-2		31.00	W271	38.3
85-11-2		32.50	W363	33.2
85-11-2		34.10	W222	13.4
85-11-2		35.40	W218	21.9

TABLE 5

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED February 6, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-1-2		1.22	w681	23.2
85-1-2		1.98	w688	24.1
85-1-2		2.74	w694	18.7
85-1-2		3.51	w691	19.7
85-1-2		4.28	w690	18.1
85-1-2		5.03	w601	17.8
85-1-2		6.10	w692	22.9
85-1-2		8.08	w673	16.3
85-1-2		9.60	w682	16.3
85-1-2		10.67	w695	20.8
85-1-2		14.17	w603	21.5
85-1-2		15.24	w693	23.0
85-1-2		16.31	w626	22.8
85-1-2		17.22	w684	22.2
85-1-2		18.74	w641	24.1
85-1-2		19.81	w604	22.8
85-1-2		21.79	w674	22.6
85-1-2		23.32	w616	25.6
85-1-2		24.84	w640	30.0
85-1-2		25.91	w650	31.2
85-1-2		27.89	w644	28.0
85-1-2		29.41	w608	41.3
85-1-2		30.48	w685	37.4

GOLDER ASSOCIATES

TABLE 5

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lse/DWMC 4B/85-GT-4
 DATE TESTED February 6, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-1-2		32.46	w683	38.5
85-1-2		33.32	w621	7.0
85-1-3		26.52	w394	32.1
85-1-3		27.13	w265	26.6
85-1-4		15.85	w306	23.0
85-1-4		16.46	w370	22.9
85-1-5		1.52	w996	24.0
85-1-5		2.13	w950	26.1
85-1-5		2.74	w979	25.2
85-1-5		3.35	w997	25.5
85-1-5		3.96	w984	26.9
85-1-5		4.57	w995	19.1
85-1-5		5.18	w992	24.2
85-1-5		5.79	w965	29.1
85-1-7		16.46	w209	20.8
85-1-8		25.15	w956	27.0
85-1-9		16.00	w969	23.4
85-11-3		23.85	w155	27.5
85-11-4		17.40	w163	25.4
85-11-4		18.00	w247	24.7
85-11-5		1.51	w21	22.4
85-11-5		2.12	w119	19.3

GOLDER ASSOCIATES

TABLE 5

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC, 4B/85-GT-4
 DATE TESTED February 6, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-11-5		2.74	w109	18.8
85-11-5		3.35	w381	18.4
85-11-5		3.96	w357	24.1
85-11-5		4.57	w104	27.0
85-11-5		5.18	w97	23.5
85-11-5		5.79	w816	21.6
85-12-2		1.20	w887	21.7
85-12-2		2.00	w947	21.1
85-12-2		2.70	w986	20.6
85-12-2		3.80	w942	21.2
85-12-2		5.00	w968	28.3
85-12-2		6.60	w972	29.9
85-12-2		8.10	w962	18.6
85-12-2		9.60	w951	19.1
85-12-2		10.70	w927	20.8
85-12-2		12.60	w931	18.4
85-12-2		14.20	w939	20.8
85-12-2		15.70	w990	17.4
85-12-2		16.80	w973	26.2
85-12-2		18.70	w896	20.4
85-12-2		20.30	w978	27.3
85-12-2		21.30	w888	23.5
85-12-2		23.30	w981	34.1

TABLE 5

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED February 6, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-12-2		24.80	w946	27.3
85-12-2		25.90	w943	24.9
85-12-2		27.90	w880	28.2
85-12-2		29.40	w994	23.5
85-12-2		30.40	w967	28.6
85-12-2		32.50	w885	33.1
85-12-2		34.00	w952	36.5
85-12-2		35.50	w861	24.7
85-12-3		26.50	w804	29.1
85-12-3		27.10	w858	33.3
85-12-4		17.40	w814	23.6
85-12-4		18.00	w820	23.1
85-12-5		1.50	w835	20.1
85-12-5		2.13	w824	20.0
85-12-5		2.74	w828	19.3
85-12-5		3.35	w859	20.0
85-12-5		3.96	w815	18.1
85-12-5		4.57	w740	18.0
85-12-5		5.18	w850	24.0
85-12-5		5.79	w833	23.2
85-12-7		17.60	w851	18.0
85-12-9		25.15	w934	30.8
85-12-11		9.14	w787	18.4

TABLE 5

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
DATE TESTED February 6, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-12-11		9.75	w772	18.9

TABLE 6

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/OWMC 4B/85-GT-4
 DATE TESTED March 17, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-13-1		1.36	W-877	22.1
85-13-1		2.88	W-1078	24.4
85-13-1		4.40	W-1041	29.4
85-13-1		5.92	W-1088	19.4
85-13-1		7.44	W-1050	18.4
85-13-1		8.96	W-1069	16.6
85-13-1		10.48	W-1093	16.8
85-13-1		12.00	W-920	19.9
85-13-1		13.52	W-1059	18.0
85-13-1		15.04	W-1070	18.6
85-13-1		16.56	W-1051	22.6
85-13-1		18.08	W-892	18.8
85-13-1		19.60	W-1092	18.1
85-13-1		21.12	W-926	20.9
85-13-1		22.64	W-936	20.5
85-13-1		24.16	W-989	22.1
85-13-1		25.68	W-919	30.6
85-13-1		27.20	W-977	23.8
85-13-1		28.72	W-977	23.8
85-13-1		30.24	W-999	22.8
85-13-1		31.76	W-904	25.7
85-13-1		32.22	W-1075	35.6
85-13-1		34.8	W-906	27.2

TABLE 6

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED March 17, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-13-1		36.32	W-964	27.1
85-13-1		37.44	W-941	7.9
85-13-2		1.52	W-1056	19.6
85-13-2		2.13	W-1018	20.8
85-13-2		2.74	W-1083	20.5
85-13-2		3.35	W-929	22.2
85-13-2		3.96	W-1053	25.7
85-13-2		4.57	W-987	30.9
85-13-2		5.18	W-1089	27.6
85-13-2		5.79	W-1063	20.9
85-14-1		1.46	W-1085	20.4
85-14-1		2.78	W-1042	30.7
85-14-1		4.50	W-898	24.9
85-14-1		6.02	W-1057	24.2
85-14-1		7.54	W-1080	26.5
85-14-1		9.06	W-1074	20.3
85-14-1		10.58	W-897	21.2
85-14-1		12.10	W-1050	21.0
85-14-1		13.62	W-884	24.3
85-14-1		15.14	W-998	21.7
85-14-1		16.66	W-1068	23.1
85-14-1		18.18	W-874	27.1
85-14-1		19.70	W-993	25.7

TABLE 6

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED March 17, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-14-1		21.22	W-891	35.7
85-14-1		22.74	W-1086	29.0
85-14-1		24.26	W-1077	27.3
85-14-1		25.78	W-930	33.7
85-14-1		27.90	W-863	38.4
85-14-1		28.82	W-937	31.5
85-14-1		30.34	W-857	7.5
85-14-1		33.66	W-1043	6.0
85-14-1		36.73	W-1033	8.0
85-14-2		1.52	W-1065	24.9
85-14-2		2.13	W-901	22.2
85-14-2		2.74	W-1081	34.3
85-14-2		3.35	W-975	29.2
85-14-2		3.96	W-916	26.6
85-14-2		4.57	W-870	27.9
85-14-2		5.18	W-953	23.9
85-14-2		5.79	W-918	23.2
85-15-1		1.57	W-800	31
85-15-1		3.04	W-605	30.2
85-15-1		4.56	W-666	21.9
85-15-1		6.08	W-661	21.7
85-15-1		7.60	W-668	23.0
85-15-1		9.12	W-611	21.9

TABLE 6

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED March 17, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-15-1		10.64	W-606	21.2
85-15-1		12.16	W-639	28.8
85-15-1		13.66	W-654	38.9
85-15-1		15.20	W-632	28.3
85-15-1		16.72	W-142	23.2
85-15-1		18.24	W-615	25.5
85-15-1		19.76	W-620	24.4
85-15-1		21.28	W-657	23.4
85-15-1		23.80	W-617	35.5
85-15-1		24.32	W-676	28.9
85-15-1		25.84	W-655	32.2
85-15-1		27.36	W-672	28.3
85-15-1		28.88	W-696	29.7
85-15-1		30.40	W-102	40.9
85-15-1		31.92	W-646	34.5
85-15-1		33.44	W-124	37.4
85-15-1		34.96	W-164	15.7
85-15-2		1.51	W-601	27.8
85-15-2		1.97	W-188	26.0
85-15-2		2.58	W-697	31.1
85-15-2		3.19	W-651	18.4
85-15-2		3.80	W-625	28.3
85-15-2		4.41	W-645	27.0

TABLE 6

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
 PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
 DATE TESTED March 17, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-15-2		5.02	W-665	27.8
85-15-2		5.63	W-658	27.2
85-16-1		1.32	W-1064	21.5
85-16-1		2.84	W-1076	20.5
85-16-1		4.36	W-957	26.6
85-16-1		5.88	W-875	21.5
85-16-1		7.40	W-895	27.2
85-16-1		8.92	W-1082	25.2
85-16-1		10.44	W-1061	21.3
85-16-1		11.96	W-935	17.6
85-16-1		13.48	W-928	19.1
85-16-1		15.00	W-894	18.7
85-16-1		16.52	W-865	19.6
85-16-1		18.04	W-911	16.6
85-16-1		19.56	W-914	20.7
85-16-1		21.08	W-948	29.9
85-16-1		22.60	W-871	36.8
85-16-1		24.12	W-915	22.1
85-16-1		25.64	W-915	22.1
85-16-2		1.53	W-110	24.7
85-16-2		2.14	W-1077	26.9
85-16-2		2.75	W-1079	29.8
85-16-2		3.36	W-980	32.1

TABLE 6

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER 851-1298
PROJECT NAME Gartner Lee/DWMC 4B/85-GT-4
DATE TESTED March 17, 1986

Borehole No.	Sample No.	Depth M	GLA Tare No.	Water Content %
85-16-2		3.97	W-883	21.4
85-16-2		4.58	W-899	26.2
85-16-2		5.19	W-909	28.5
85-16-2		5.80	W-1091	26.7
			W-147	16.2
			W-656	19.8
			W-932	17.5
			W-938	18.4
			W-985	18.0

May, 1986

851-1298

SUMMARY OF LABORATORY VANE TEST RESULTS

TABLE 7

TABLE 7

JOB NO: 851-1298

GLAL : 85-GT-4

SUMMARY OF LABORATORY VANE TEST RESULTS
 VANE ORIENTATION - DEGREES TO HORIZONTAL PLANE

BOREHOLE NO.	SAMPLE NO.	VANE DEGREE	PEAK STRENGTH kPa	REMOULDED STRENGTH kPa	WATER CONTENT %	REMARKS
85- 1-2	7	90	166.5	5.2	29.5	
85- 1-2	11	90	135.1	8.4	21.1	
85- 1-2	21	90	122.5	13.6	22.6	
85- 1-2	21	0	96.4	9.4	23.5	
85- 1-2	21	40	82.7	7.3	20.7	BASE
85- 1-2	21	38	76.4	6.3	22.2	TOP
85- 1-2	30	90	54.5	3.1	40.2	
85- 8-2	4	90	>186.4	-	20.6	
85- 8-2	7	90	>186.4	-	21.3	
85- 8-2	7	0	>186.4	-	29.5	
85- 8-2	7	34	>186.4	-	20.7	BASE
85- 8-2	7	32	>186.4	-	20.1	TOP
85- 8-2	12	90	77.5	10.5	20.5	
85- 8-2	12	0	66.0	7.3	20.1	
85- 8-2	12	35	70.2	9.4	19.4	BASE
85- 8-2	12	35	71.2	9.4	20.0	TOP
85- 8-2	17	90	79.6	8.4	26.6	
85- 8-2	17	0	76.5	7.3	26.4	
85- 8-2	22	90	77.5	8.4	31.8	
85- 8-2	27	90	68.1	7.3	32.9	
85-12-2	4	90	>186.4	-	20.8	
85-12-2	10	90	>186.4	-	17.6	
85-12-2	10	0	173.9	9.4	19.5	
85-12-2	10	38	163.4	8.4	16.8	BASE
85-12-2	10	34	137.2	12.6	18.1	TOP
85-12-2	15	90	121.5	10.5	18.5	
85-12-2	15	0	121.5	8.4	22	
85-12-2	15	38	122.5	7.3	21	BASE
85-12-2	15	37	138.2	12.6	22	TOP
85-12-2	19	90	114.2	10.5	22.6	
85-12-2	19	0	183.2	8.4	17.3	
85-12-2	27	90	82.7	7.3	27.7	

ANGULAR TEST CARRIED OUT ON A 4 INCH SECTION OF SAMPLE WHICH WAS CUT FROM SHELBY TUBE.

Golder Associates

May, 1986

851-1298

UNDRAINED TRIAXIAL COMPRESSION (Q)

FIGURES 1-1 to 11-2

UNDRAINED TRIAXIAL COMPRESSION (Q)

FIGURE 1-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.133
BOREHOLE NUMBER	85-5-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	6	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	4.27	BH. 85-5-2 SA. 6	

SAMPLE HEIGHT, cm	10.21	WET WEIGHT, gm	389.1
SAMPLE DIAMETER, cm	5.03	DRY WEIGHT, gm	295.2
SAMPLE AREA, cm ²	19.87	WATER CONTENT, %	31.8
SAMPLE VOLUME, cc	202.89	POROSITY, %	47.7
UNIT WEIGHT, kN/m ³	18.80	DRY UNIT WT., kN/m ³	14.26

TEST RESULTS		LIQUID LIMIT, %	55
COMPRESS. STRESS, kPa	158.9	PLASTIC INDEX, %	24
STRAIN AT FAILURE, %	2.0	LAB. VANE, Peak, kPa	86.9
CELL PRESSURE, kPa	80.6	LAB. VANE, Resid., kPa	12.6

Strain Dial %	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.0	64.0	0.25	41.90
51.0	130.0	0.50	84.90
76.0	169.0	0.75	110.10
102.1	200.0	1.00	129.96
153.1	235.0	1.50	151.94
204.1	247.0	2.00	158.89
255.1	247.0	2.50	158.08
306.1	247.0	3.00	154.72

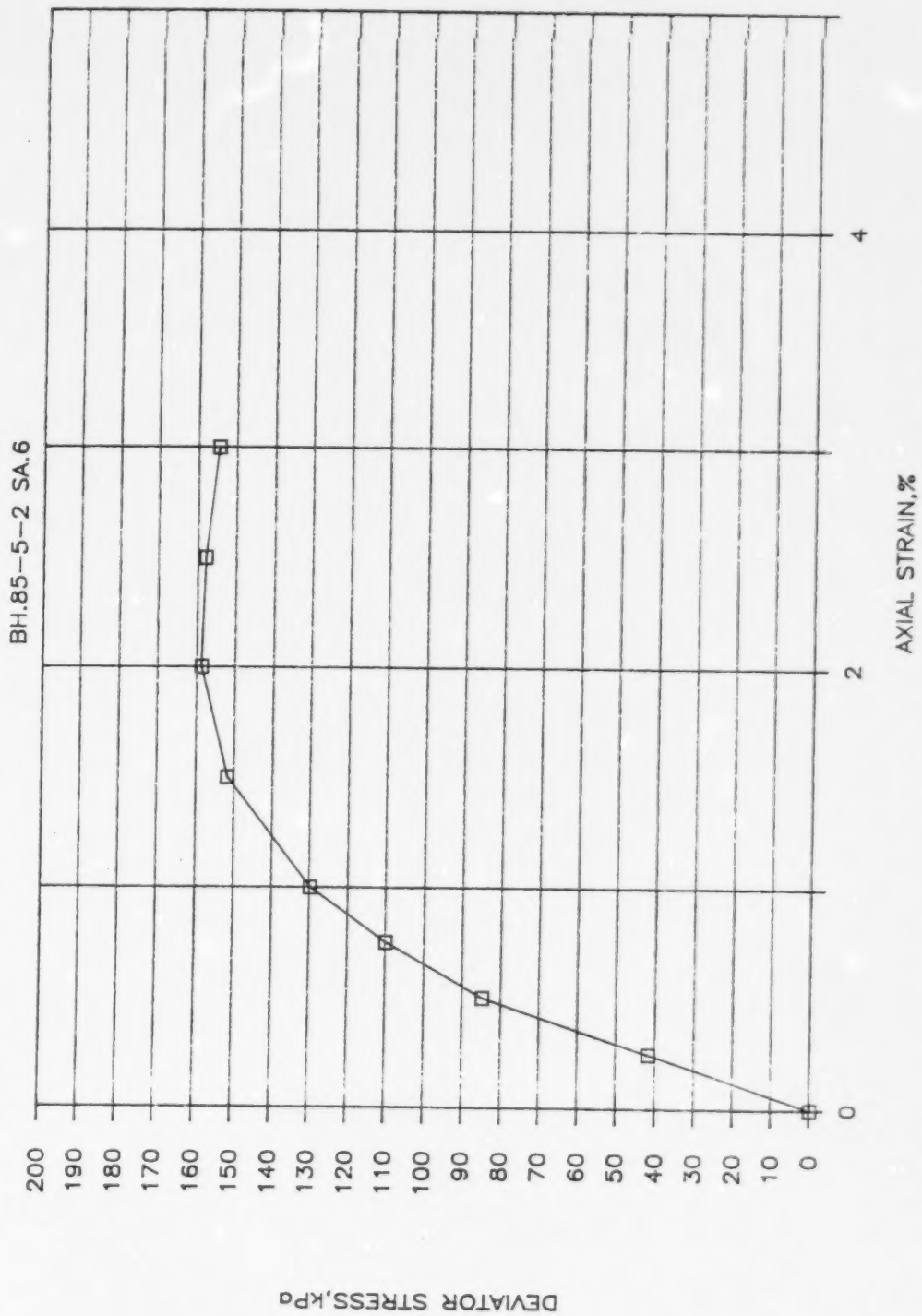
PROJECT 851-1298 (CLAL PROJECT # 85-6T-4)

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UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 1-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

FIGURE 2-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.133
BOREHOLE NUMBER	85-5-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	10	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	6.54	BH. 85-5-2 SA. 10	

SAMPLE HEIGHT, cm	10.14	WET WEIGHT, gm	439.4
SAMPLE DIAMETER, cm	5.03	DRY WEIGHT, gm	372.9
SAMPLE AREA, cm ²	19.87	WATER CONTENT, %	17.8
SAMPLE VOLUME, cc	201.49	POROSITY, %	33.4
UNIT WEIGHT, kN/m ³	21.38	DRY UNIT WT., kN/m ³	18.14

TEST RESULTS		LIQUID LIMIT, %	
COMPRESS. STRESS, kPa	266.8	PLASTIC INDEX, %	
STRAIN AT FAILURE, %	7.0	LAB. VANE, Peak, kPa	140.3
CELL PRESSURE, kPa	185.3	LAB. VANE, Resid. kPa	28.3

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.3	52.0	0.25	34.05
50.6	92.0	0.50	60.09
75.9	136.0	0.75	88.60
101.4	188.0	1.00	122.17
152.0	272.0	1.50	175.86
202.6	318.0	2.00	204.56
253.2	348.0	2.50	222.72
303.8	367.0	3.00	233.68
354.4	385.0	3.49	243.88
405.0	398.0	3.99	250.81
455.6	410.0	4.49	257.03
506.2	420.0	4.99	261.92
607.6	431.0	5.99	265.95
709.0	437.0	6.99	266.78
810.4	440.0	7.99	265.73
911.8	444.0	8.99	265.23
1013.2	446.0	9.99	263.50
1114.6	448.0	10.99	261.74
1216.0	450.0	11.99	259.95
1317.4	453.0	12.99	257.80
1418.8	449.0	13.99	253.48

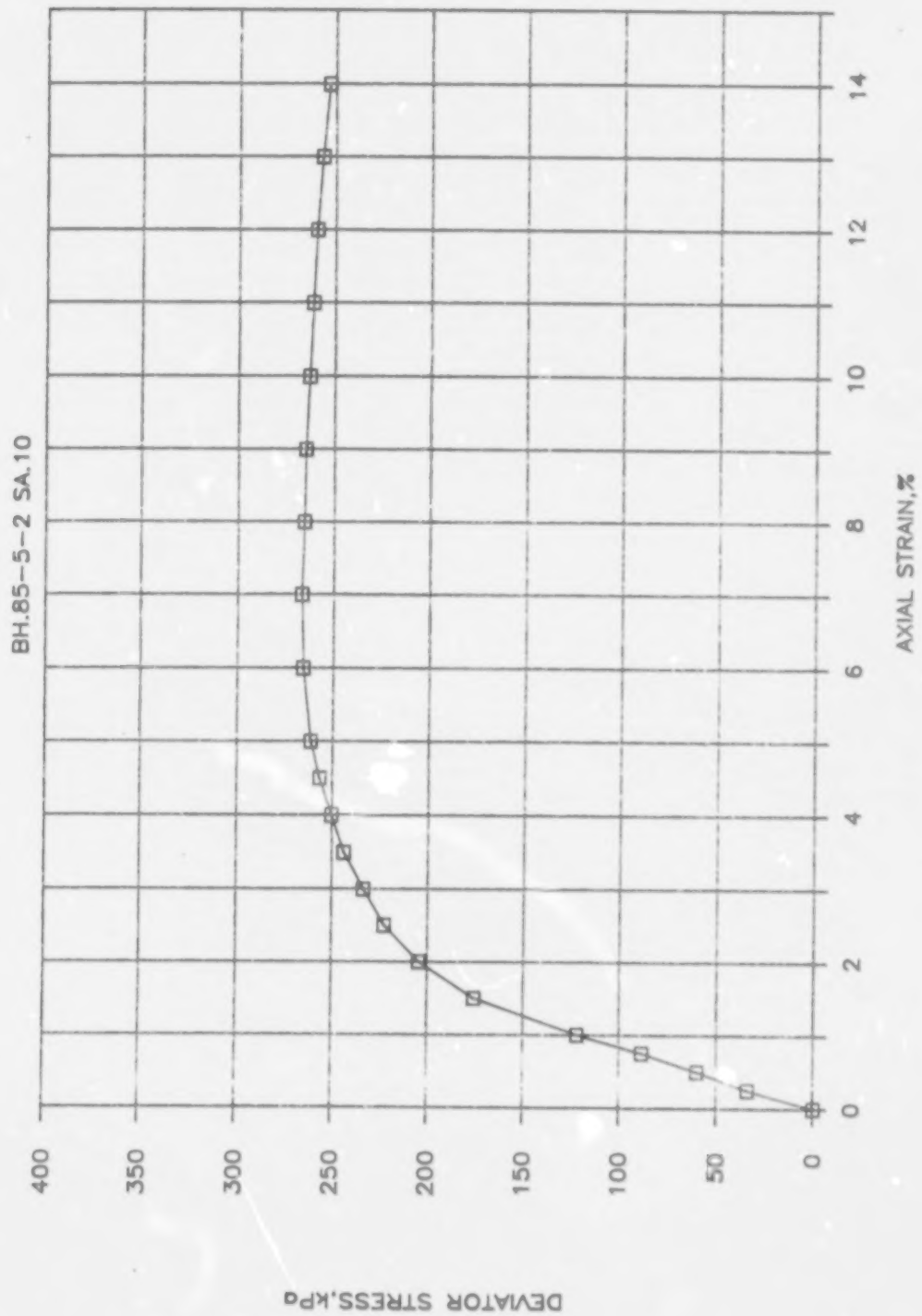
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 2-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

FIGURE 3-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.133
BOREHOLE NUMBER	85-5-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	18	SPECIFIC GRAVITY, assumed	2.70
SAMPLE DEPTH, m	16.00	BH. 85-5-2 SA. 18	

SAMPLE HEIGHT, cm	10.11	WET WEIGHT, gm	415.6
SAMPLE DIAMETER, cm	4.98	DRY WEIGHT, gm	339.2
SAMPLE AREA, cm ²	19.48	WATER CONTENT, %	22.5
SAMPLE VOLUME, cc	196.92	POROSITY, %	38.0
UNIT WEIGHT, kN/m ³	20.69	DRY UNIT WT., kN/m ³	16.89

TEST RESULTS		LIQUID LIMIT, %	37
COMPRESS. STRESS, kPa	182.9	PLASTIC INDEX, %	17
STRAIN AT FAILURE, %	13.0	LAB. VANE, Peak, kPa	83.8
CELL PRESSURE, kPa	248.7	LAB. VANE, Resid. kPa	9.4

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.3	26.0	0.25	17.37
50.6	37.0	0.50	24.65
75.9	44.0	0.75	29.24
101.1	50.0	1.00	33.15
151.7	61.0	1.50	40.23
202.3	72.0	2.00	47.25
252.9	84.0	2.50	54.84
303.5	94.0	3.00	61.06
354.1	106.0	3.50	68.49
404.7	122.0	4.00	78.43
455.3	138.0	4.50	88.25
505.9	155.0	5.00	98.60
607.0	190.0	6.00	119.59
708.1	224.0	7.00	139.49
809.2	252.0	8.00	155.24
910.3	274.0	9.00	166.96
1011.4	290.0	10.00	174.77
1112.5	301.0	11.00	179.38
1213.6	309.0	12.00	182.06
1314.7	314.0	13.00	182.92
1415.8	317.0	14.00	182.55
1516.9	318.0	15.00	180.99
1618.0	319.0	16.00	179.43
1719.1	333.0	17.00	185.07
1820.2	343.0	18.00	188.33
1921.3	351.0	19.00	190.37
2022.4	356.0	20.00	190.70

PROJECT 851-1298

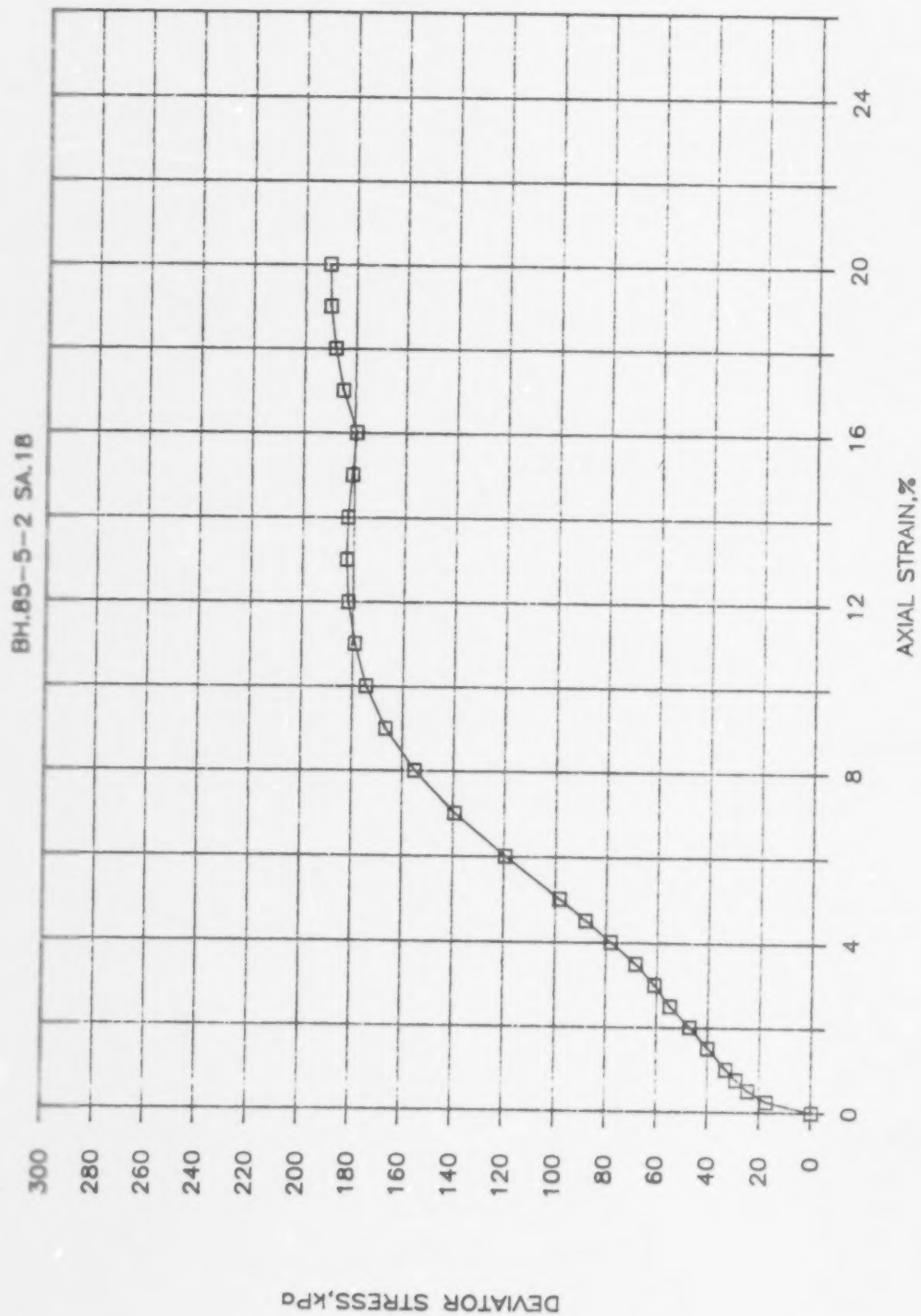
(GLAL PROJECT # 85-67-4)

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UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 3-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 1 OF 2

FIGURE 4-1

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	651-1298	PROVING RING, kg/mm div.	0.133
BOREHOLE NUMBER	85-5-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	23	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	22.30	BH. 85-5-2 SA. 23	

SAMPLE HEIGHT, cm	12.12	WET WEIGHT, gm	403.0
SAMPLE DIAMETER, cm	5.01	DRY WEIGHT, gm	318.9
SAMPLE AREA, cm ²	19.71	WATER CONTENT, %	26.4
SAMPLE VOLUME, cc	199.50	POROSITY, %	42.5
UNIT WEIGHT, kN/m ³	19.80	DRY UNIT WT., kN/m ³	15.67

TEST RESULTS		LIQUID LIMIT, %	37
COMPRESS. STRESS, kPa	141.2	PLASTIC INDEX, %	15
STRAIN AT FAILURE, %	16.0	LAB. VANE, Peak, kPa	60.7
CELL PRESSURE, kPa	443.7	LAB. VANE, Resid. kPa	6.3

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.3	20.0	0.25	13.20
50.6	38.0	0.50	25.02
75.9	46.0	0.75	30.21
101.2	52.0	1.00	34.06
151.0	60.0	1.50	39.10
202.4	70.0	2.00	45.39
253.0	80.0	2.50	51.61
303.6	90.0	3.00	57.76
354.2	101.0	3.50	64.49
404.8	118.0	4.00	74.95
455.4	130.0	4.50	82.14
506.0	146.0	5.00	91.77
607.2	176.0	6.00	109.46
708.4	196.0	7.00	120.60
809.6	208.0	8.00	126.61
910.8	218.0	9.00	131.26
1012.0	227.0	10.00	135.17
1113.2	233.0	11.00	137.20
1214.4	239.0	12.00	139.16
1315.6	247.0	13.00	140.78
1416.8	248.0	14.00	141.11
1518.0	251.0	15.00	141.16
1619.2	254.0	16.00	141.17
1720.4	258.0	17.00	141.68
1821.6	260.0	18.00	141.06
1922.8	262.0	19.00	140.41
2024.0	264.0	20.00	139.74

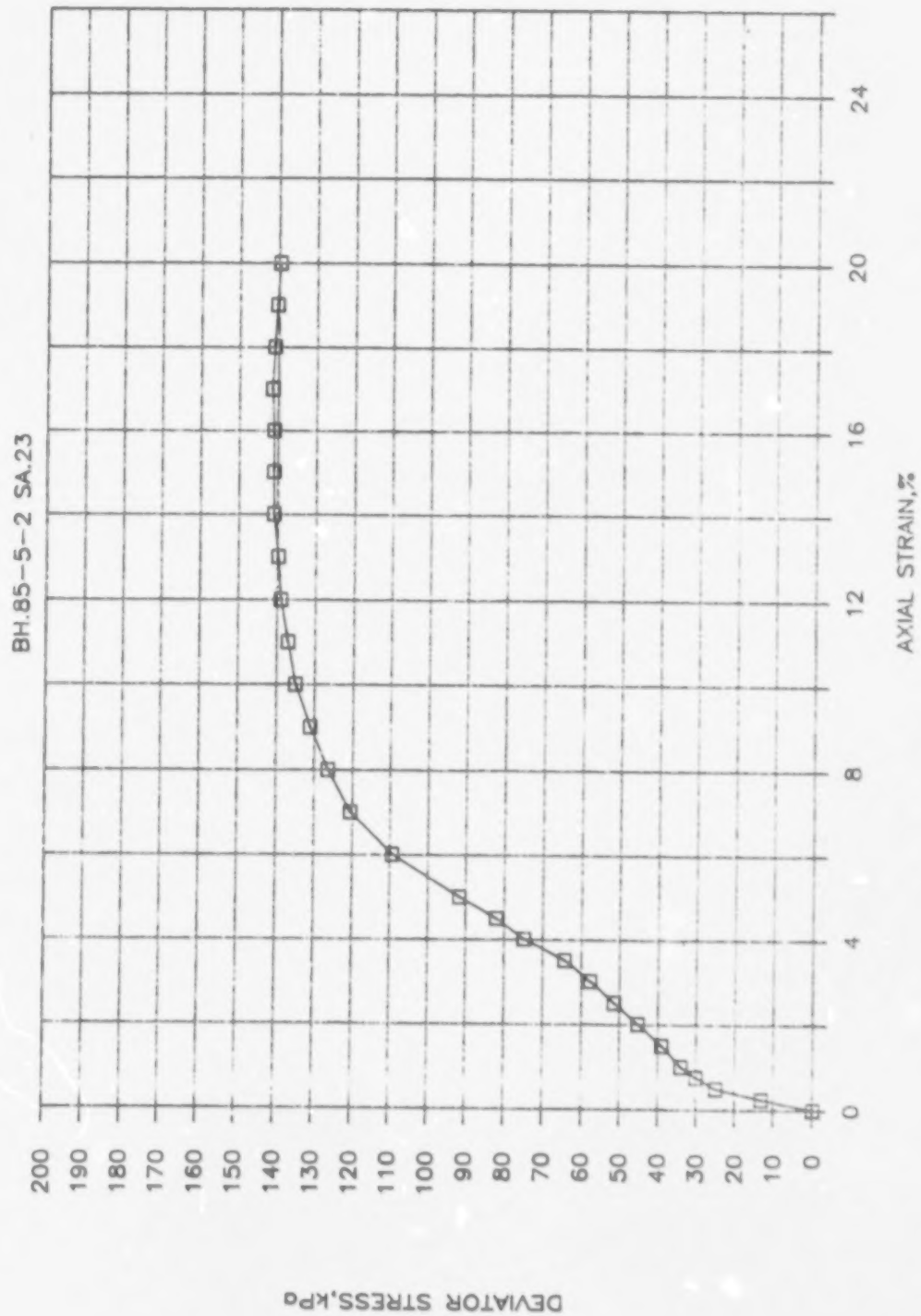
PROJECT 651-1298 (GLAL PROJECT # 85-GT-4)

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UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 4-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 1 OF 2

FIGURE 5-1

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.118
BOREHOLE NUMBER	85-5-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	26	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	25.18	BH. 85-5-2 SA. 26	

SAMPLE HEIGHT, cm	18.10	WET WEIGHT, gm	391.4
SAMPLE DIAMETER, cm	5.02	DRY WEIGHT, gm	295.0
SAMPLE AREA, cm ²	19.79	WATER CONTENT, %	32.7
SAMPLE VOLUME, cc	199.98	POROSITY, %	46.9
UNIT WEIGHT, kN/m ³	19.19	DRY UNIT WT., kN/m ³	14.47

TEST RESULTS		LIQUID LIMIT, %	40.5
COMPRESS. STRESS, kPa	133.3	PLASTIC INDEX, %	19.3
STRAIN AT FAILURE, %	5.0	LAB. VANE, Peak, kPa	51.38
CELL PRESSURE, kPa	461.6	LAB. VANE, Resid. kPa	13.6

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.2	38.0	0.25	22.16
50.4	58.0	0.50	33.74
75.6	78.0	0.75	45.26
101.8	98.0	1.00	56.73
151.4	121.0	1.50	69.69
201.8	153.0	2.00	87.67
252.2	179.0	2.50	102.04
302.6	201.0	3.00	114.00
353.0	220.0	3.49	124.13
403.4	232.0	3.99	130.23
453.8	238.0	4.49	132.90
504.2	240.0	4.99	133.32
605.2	242.0	5.99	133.01
706.2	242.0	6.99	131.60
807.2	242.0	7.99	130.18
908.2	242.0	8.99	128.77
1009.2	242.0	9.99	127.35
1110.2	237.0	10.99	123.34
1211.2	235.0	11.99	120.92

PROJECT 851-1298

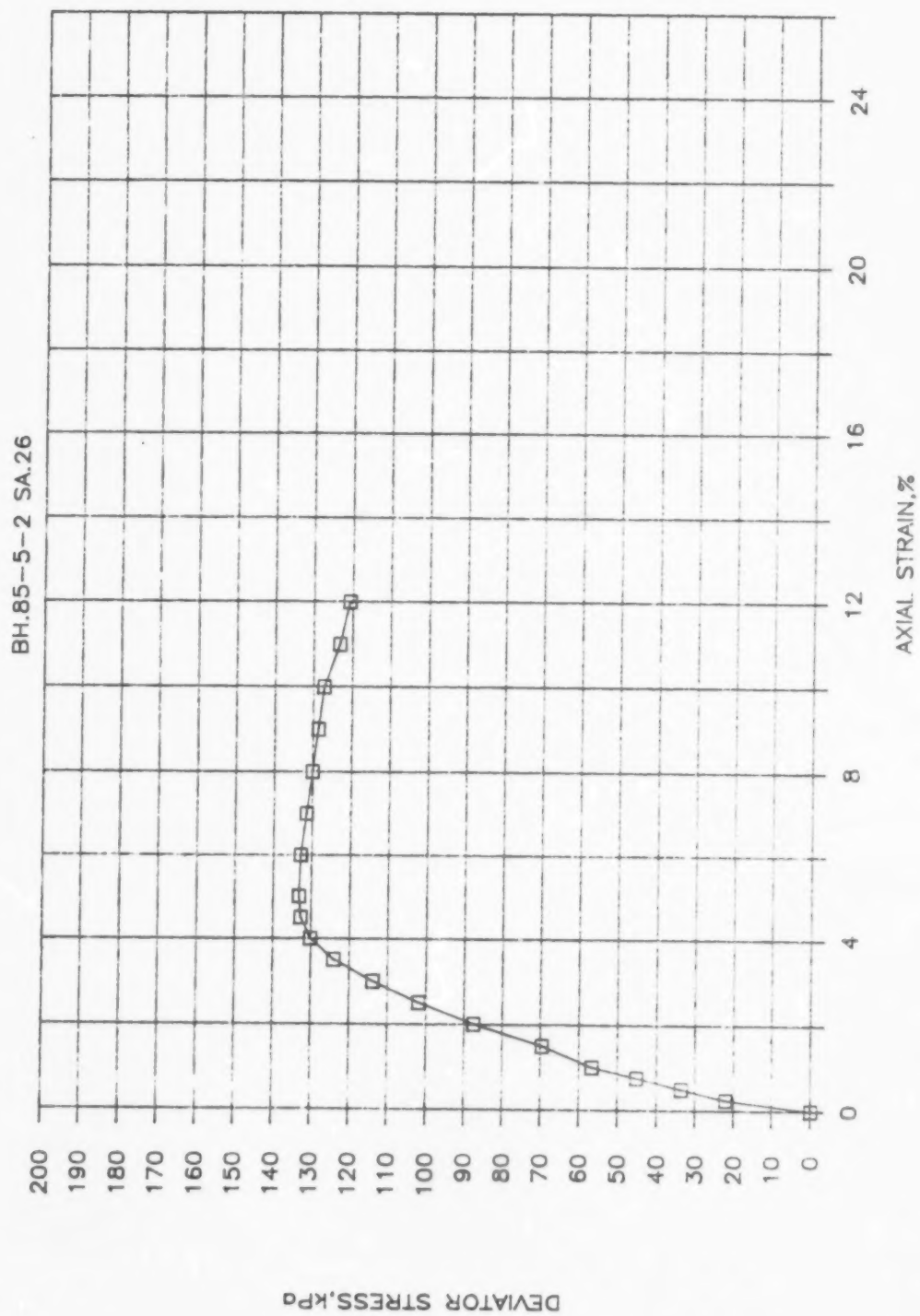
(GLAL PROJECT # 85-GT-4)

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UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 5-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 1 OF 2

FIGURE 6-1

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.133
BOREHOLE NUMBER	85-5-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	30	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	29.70	BH. 85-5-2 SA. 30	
SAMPLE HEIGHT, cm	10.16	WET WEIGHT, gm	395.7
SAMPLE DIAMETER, cm	5.03	DRY WEIGHT, gm	301.4
SAMPLE AREA, cm ²	19.87	WATER CONTENT, %	31.3
SAMPLE VOLUME, cc	201.89	POROSITY, %	46.3
UNIT WEIGHT, kN/m ³	19.21	DRY UNIT WT., kN/m ³	14.63
TEST RESULTS		LIQUID LIMIT, %	38
COMPRESS. STRESS, kPa	145.9	PLASTIC INDEX, %	19
STRAIN AT FAILURE, %	10.0	LAB. VANE, Peak, kPa	64.9
CELL PRESSURE, kPa	488.5	LAB. VANE, Resid. kPa	5.2

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.4	20.0	0.25	13.09
50.8	46.0	0.50	30.04
76.2	55.0	0.75	35.83
101.6	61.0	1.00	39.64
152.4	75.0	1.50	48.49
203.2	88.0	2.00	56.61
254.0	96.0	2.50	62.72
304.8	113.0	3.00	71.95
355.6	125.0	3.50	79.18
406.4	138.0	4.00	86.96
457.2	154.0	4.50	96.53
508.0	168.0	5.00	104.76
609.6	194.0	6.00	119.70
711.2	216.0	7.00	131.86
812.8	232.0	8.00	140.10
914.4	242.0	9.00	144.55
1016.0	247.0	10.00	145.92
1117.6	249.0	11.00	145.46
1219.2	250.0	12.00	144.41
1320.8	240.0	13.00	141.00
1422.4	241.0	14.00	138.04

PROJECT 851-1298

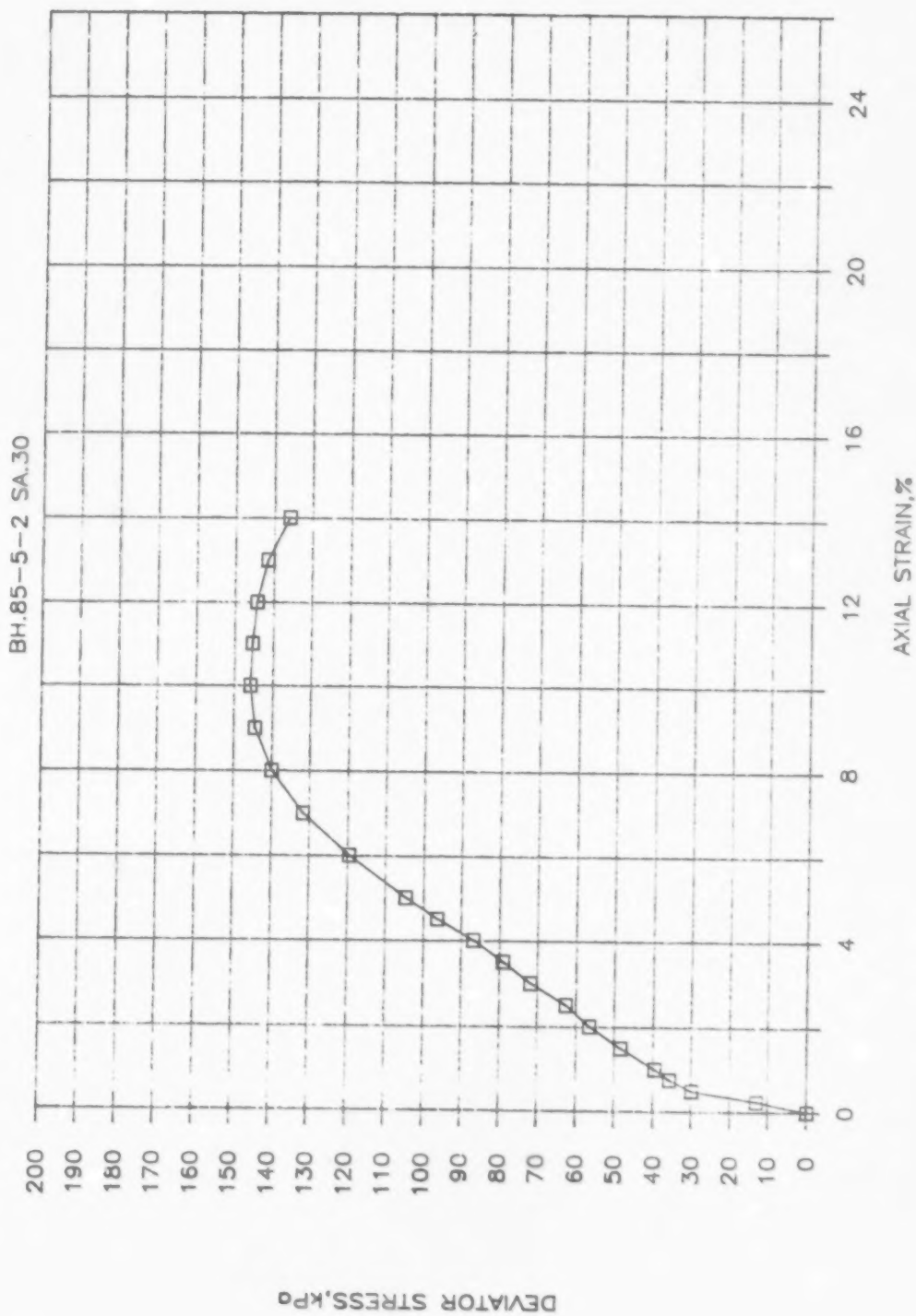
(GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 6-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 1 OF 2

FIGURE 7-1

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.133
BOREHOLE NUMBER	85-8-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	4	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	3.1	BH. 85-8-2 SA. 4	

SAMPLE HEIGHT, cm	10.19	WET WEIGHT, gm	436.2
SAMPLE DIAMETER, cm	5.12	DRY WEIGHT, gm	361.8
SAMPLE AREA, cm ²	20.59	WATER CONTENT, %	20.6
SAMPLE VOLUME, cc	209.80	POROSITY, %	38.0
UNIT WEIGHT, kN/m ³	20.38	DRY UNIT WT., kN/m ³	16.91

TEST RESULTS		LIQUID LIMIT, %	34
COMPRESS. STRESS, kPa	503.8	PLASTIC INDEX, %	15
STRAIN AT FAILURE, %	3.5	LAB. VANE, Peak, kPa	>185.4
CELL PRESSURE, kPa	43.4	LAB. VANE, Resid., kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.5	122.0	0.25	77.10
51.0	242.0	0.50	152.54
76.5	360.0	0.75	226.35
101.9	460.0	1.00	288.50
152.9	590.0	1.50	368.17
203.9	700.0	2.00	434.59
254.9	770.0	2.50	475.60
305.9	812.0	3.00	498.97
356.4	824.0	3.50	503.76
407.9	810.0	4.00	492.61

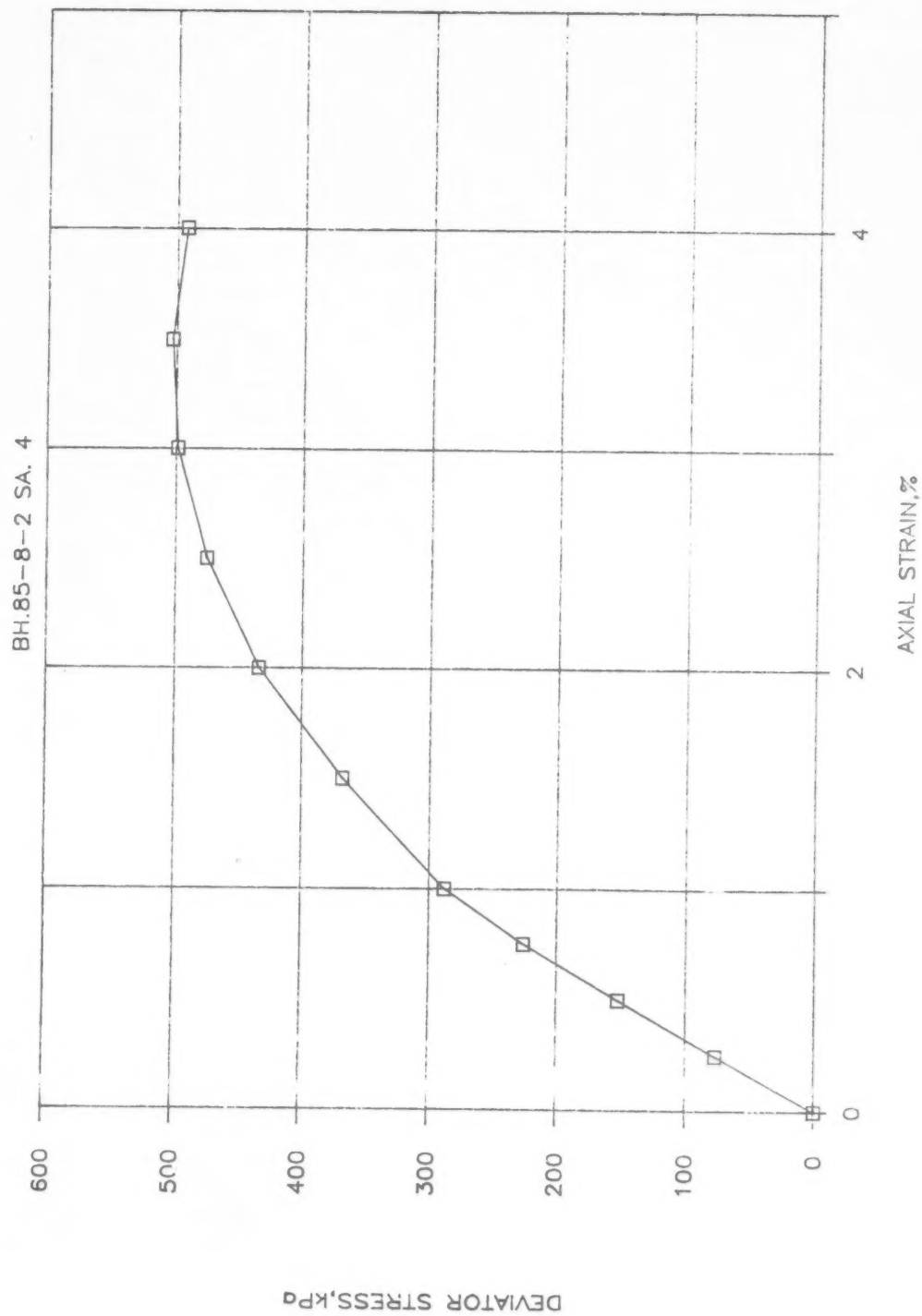
PROJECT 851-1298 (GLAL PROJECT #85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 7-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 1 OF 2

FIGURE 8-1

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.133
BOREHOLE NUMBER	85-8-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	7	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	5.8	BH. 85-8-2 SA. 7	

SAMPLE HEIGHT, cm	10.12	WET WEIGHT, gm	406.7
SAMPLE DIAMETER, cm	4.99	DRY WEIGHT, gm	335.3
SAMPLE AREA, cm ²	19.56	WATER CONTENT, %	21.3
SAMPLE VOLUME, cc	197.91	POROSITY, %	39.1
UNIT WEIGHT, kN/m ³	20.14	DRY UNIT WT., kN/m ³	16.61

TEST RESULTS		LIQUID LIMIT, %	38
COMPRESS. STRESS, kPa	291.1	PLASTIC INDEX, %	21
STRAIN AT FAILURE, %	4.5	LAB. VANE, Peak, kPa	>186.4
CELL PRESSURE, kPa	86.1	LAB. VANE, Resid., kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.3	55.0	0.25	36.59
50.6	112.0	0.50	74.33
75.9	152.0	0.75	100.62
101.2	200.0	1.00	132.06
151.8	290.0	1.50	190.52
202.4	355.0	2.00	232.03
253.0	402.0	2.50	261.41
303.6	428.0	3.00	276.89
354.2	446.0	3.50	287.05
404.8	454.0	4.00	290.68
455.4	457.0	4.50	291.08
506.0	458.0	5.00	290.19
607.2	448.0	6.00	280.87
708.4	432.0	7.00	267.96

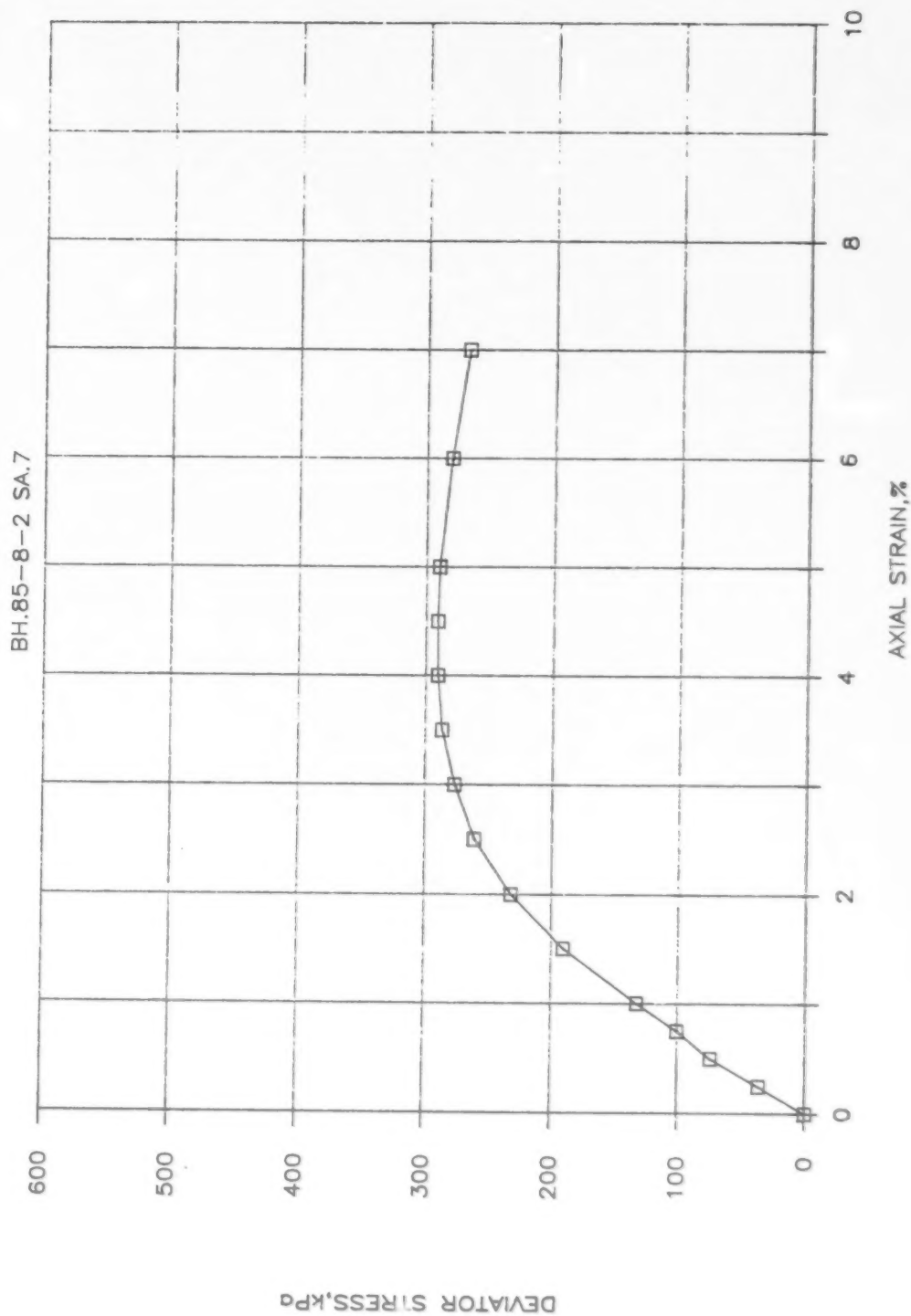
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 8-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 1 OF 2

FIGURE 9-1

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.311
BOREHOLE NUMBER	85-8-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	12	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	12.19	BH. 85-8-2 SA. 12	
SAMPLE HEIGHT, cm	10.18	WET WEIGHT, gm	428.1
SAMPLE DIAMETER, cm	5.01	DRY WEIGHT, gm	355.3
SAMPLE AREA, cm ²	19.71	WATER CONTENT, %	20.5
SAMPLE VOLUME, cc	200.68	POROSITY, %	36.3
UNIT WEIGHT, kN/m ³	20.91	DRY UNIT WT., kN/m ³	17.36
TEST RESULTS		LIQUID LIMIT, %	29
COMPRESS. STRESS, kPa	147.5	PLASTIC INDEX, %	17
STRAIN AT FAILURE, %	16.0	LAB. VANE, Peak, kPa	77.5
CELL PRESSURE, kPa	216.3	LAB. VANE, Resid., kPa	10.5

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.4	6.0	0.25	9.26
50.9	8.0	0.50	12.31
76.3	9.0	0.75	13.82
101.8	11.5	1.00	17.61
152.7	16.0	1.50	24.38
203.6	21.0	2.00	31.84
254.5	26.0	2.50	39.22
305.4	32.0	3.00	48.02
356.3	38.5	3.50	57.48
407.2	45.0	4.00	66.84
458.1	53.0	4.50	78.31
509.0	58.0	5.00	85.25
610.8	71.0	6.00	103.26
712.6	81.0	7.00	116.55
813.4	87.5	7.99	124.56
915.2	93.5	8.99	131.65
1018.0	98.0	10.00	136.46
1119.8	102.0	11.00	140.45
1221.6	105.0	12.00	142.96
1323.4	108.0	13.00	146.00
1425.2	110.0	14.00	146.36
1527.0	113.0	15.00	147.25
1628.8	113.5	16.00	147.50
1730.6	114.8	17.00	147.42
1842.4	116.0	18.10	146.99
1944.2	117.0	19.10	147.07
2046.0	116.5	20.10	144.00

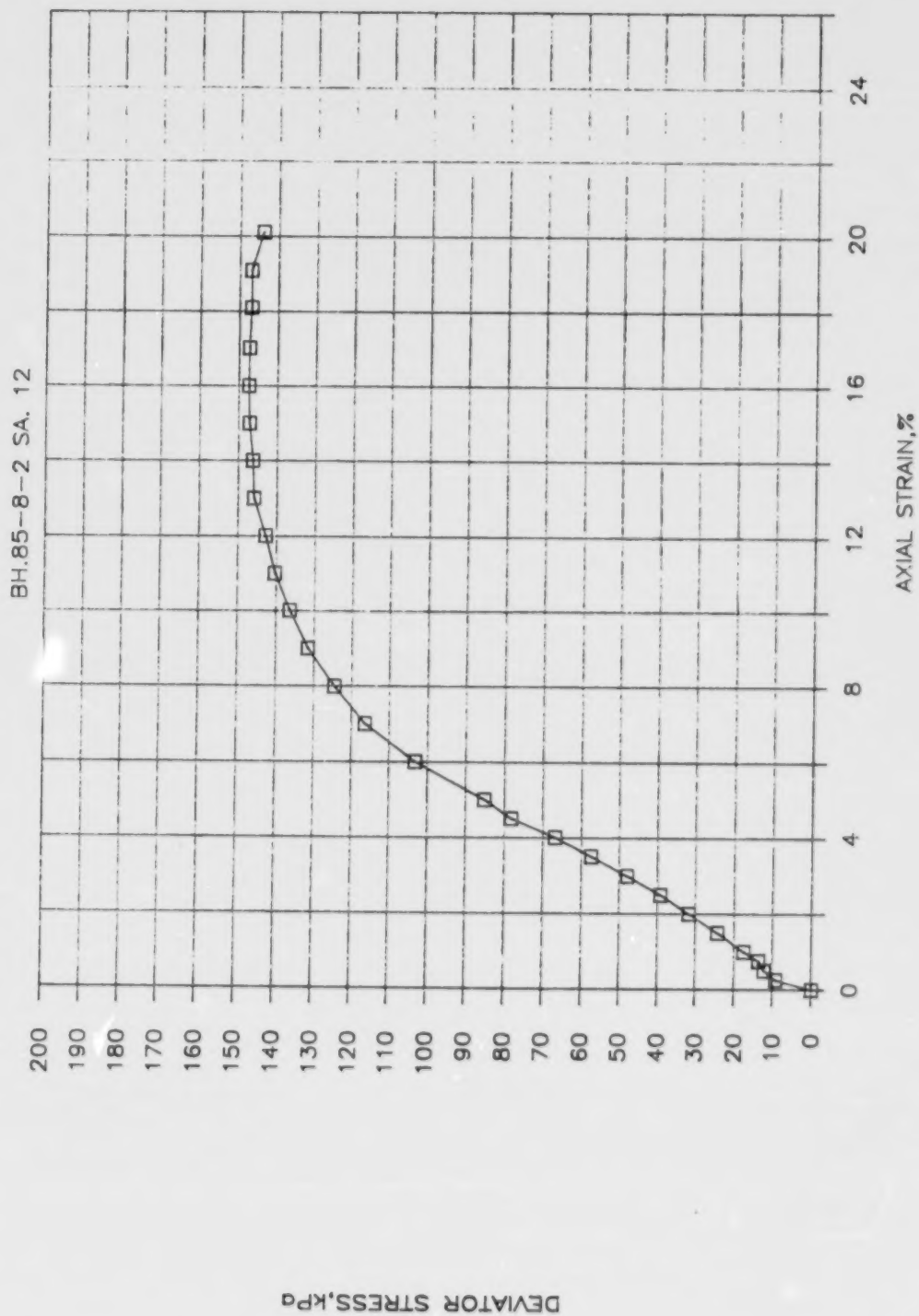
PROJECT 851-1298

(GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (Q)
SHEET 2 OF 2

FIGURE 9-2



UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 1 OF 2

FIGURE 10-1

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	951-1298	PROVING RING, kg/cm div.	0.311
BOREHOLE NUMBER	85-8-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	17	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	18.1	BH. 85-8-2 SA. 17	

SAMPLE HEIGHT, cm	10.14	WET WEIGHT, gm	405.2
SAMPLE DIAMETER, cm	5.02	DRY WEIGHT, gm	320.0
SAMPLE AREA, cm ²	19.79	WATER CONTENT, %	26.6
SAMPLE VOLUME, cc	200.69	POROSITY, %	42.6
UNIT WEIGHT, kN/m ³	19.79	DRY UNIT WT., kN/m ³	15.63

TEST RESULTS		LIQUID LIMIT, %	39
COMPRESSION STRESS, kPa	156.7	PLASTIC INDEX, %	19
STRAIN AT FAILURE, %	17.0	LAB. VANE, Peak, kPa	79.6
CELL PRESSURE, kPa	323.8	LAB. VANE, Resid., kPa	8.4

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator STRESS kPa
0.0	0.0	0	0.00
25.1	9.2	0.25	14.14
50.2	17.0	0.49	19.93
75.3	15.5	0.74	23.71
101.4	17.5	1.00	26.70
151.6	21.5	1.50	32.64
192.8	25.5	2.00	38.51
252.0	29.0	2.48	43.58
302.2	33.5	2.96	50.08
352.4	38.0	3.46	56.52
402.6	42.5	3.97	62.89
452.8	48.5	4.47	71.40
503.0	52.5	4.96	76.89
624.4	63.0	5.96	91.30
705.8	74.5	6.96	106.81
806.2	85.5	7.95	121.28
907.4	96.0	8.95	134.70
1014.0	103.0	10.00	142.85
1115.4	107.5	11.00	147.43
1216.8	113.0	12.00	153.24
1318.2	118.0	13.00	155.52
1419.6	119.0	14.00	156.38
1521.0	119.5	15.00	156.53
1622.4	121.0	16.00	156.67
1723.8	122.5	17.00	156.68
1825.5	124.0	18.00	156.68
1926.6	125.5	19.00	156.59
2028.0	126.5	20.00	155.45

PROJECT 951-1298

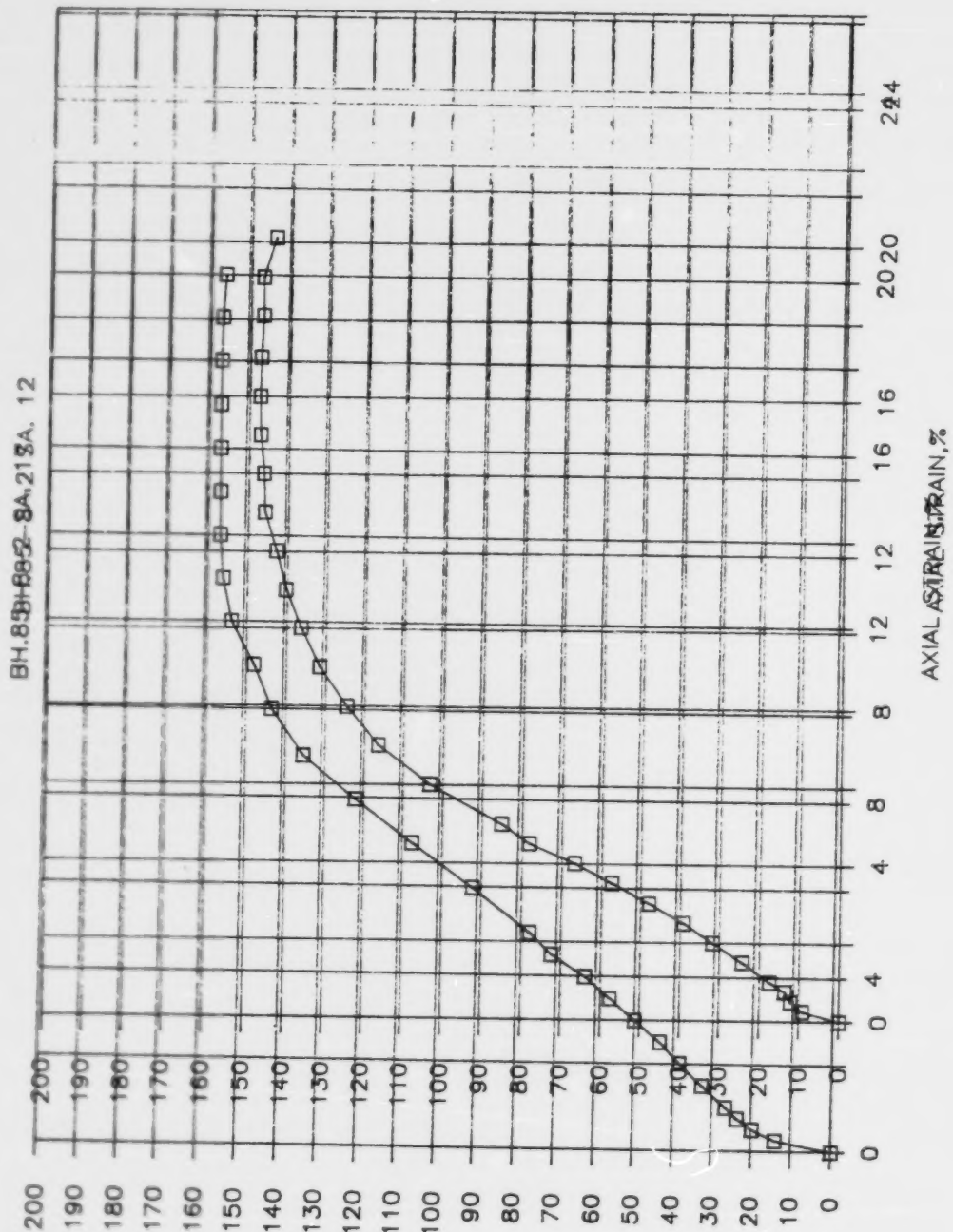
(GLAL PROJECT # 85-GT-4)

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UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 9022



DEVELOPMENT OF STRESS

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UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 1 OF 2

FIGURE 11-1

UNDRAINED TRIAXIAL COMPRESSION TEST (Q)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.311
BOREHOLE NUMBER	85-8-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	22	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	24.12	BH. 85-8-2 SA. 22	
SAMPLE HEIGHT, cm	10.19	WET WEIGHT, gm	388.6
SAMPLE DIAMETER, cm	5.00	DRY WEIGHT, gm	294.9
SAMPLE AREA, cm ²	19.63	WATER CONTENT, %	31.8
SAMPLE VOLUME, cc	200.08	POROSITY, %	47.0
UNIT WEIGHT, kN/m ³	19.04	DRY UNIT WT., kN/m ³	14.45
TEST RESULTS		LIQUID LIMIT, %	42
COMPRESS. STRESS, kPa	137.2	PLASTIC INDEX, %	20
STRAIN AT FAILURE, %	13.0	LAB. VANE, Peak, kPa	77.5
CELL PRESSURE, kPa	425.1	LAB. VANE, Resid., kPa	8.4

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator STRESS kPa
0.0	0.0	0	0.00
25.5	20.0	0.25	30.99
50.9	24.0	0.50	37.09
101.9	28.5	1.00	43.83
152.8	32.0	1.50	48.96
203.7	35.0	2.00	53.28
254.6	38.5	2.50	58.31
305.6	42.0	3.00	63.28
356.5	46.5	3.50	69.70
407.5	50.5	4.00	75.31
458.4	54.5	4.50	80.85
509.5	59.5	5.00	87.80
611.4	68.0	6.00	99.29
713.3	76.0	7.00	109.79
815.2	84.0	8.00	120.04
917.1	89.0	9.00	125.80
1019.0	93.0	10.00	130.01
1120.9	97.5	11.00	134.79
1222.8	98.5	12.00	134.64
1324.7	101.5	13.00	137.17
1426.6	102.0	14.00	136.26
1528.5	102.5	15.00	135.33
1630.4	102.5	16.00	133.74

PROJECT 851-1298

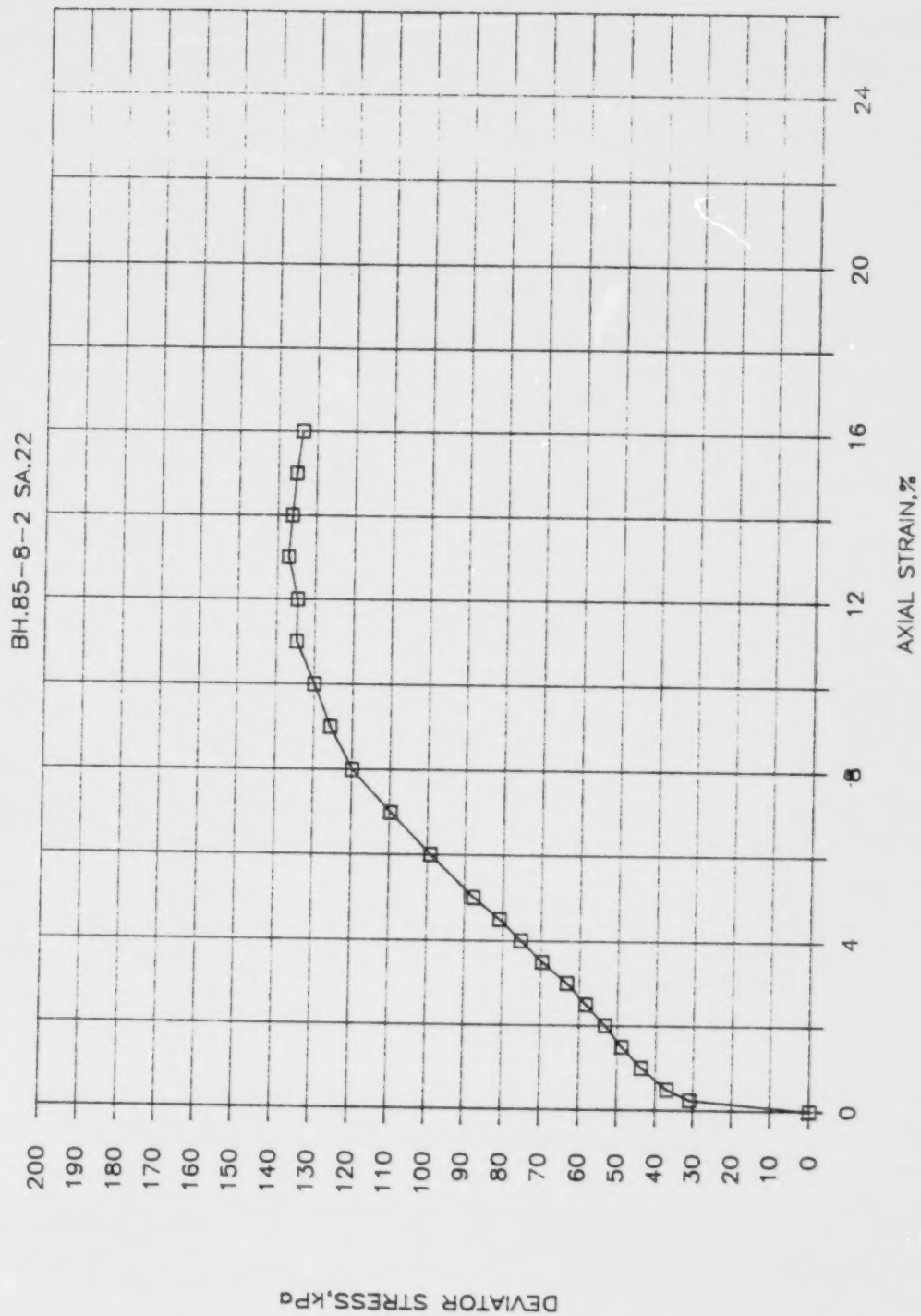
(GLAL PROJECT # 85-GT-4)

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UNDRAINED TRIAXIAL COMPRESSION (Q)

SHEET 2 OF 2

FIGURE 11-2



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May, 1986

851-1298

UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURES 12-1 to 30-2

UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 12-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-1-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	30	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	29.65	BH. 85-1-2 SA. 30 @ 90 deg.	

SAMPLE HEIGHT, cm	7.25	WET WEIGHT, gm	162.7
SAMPLE DIAMETER, cm	3.87	DRY WEIGHT, gm	123.0
SAMPLE AREA, cm ²	11.76	WATER CONTENT, %	33.1
SAMPLE VOLUME, cc	95.28	POROSITY, %	
UNIT WEIGHT, kN/m ³	18.70	DRY UNIT WT., kN/m ³	14.05

TEST RESULTS		LIQUID LIMIT, %	42
COMPRESS. STRESS, kPa	65.9	PLASTIC INDEX, %	24
STRAIN AT FAILURE, %	12.0	LAB. VANE, Peak, kPa	37.7
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	3.1

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
18.1	22.0	0.25	7.87
36.2	30.0	0.50	10.70
54.3	36.0	0.75	12.81
72.5	42.0	1.00	14.91
108.7	53.0	1.50	18.72
144.9	65.0	2.00	22.84
181.1	76.0	2.50	26.57
217.3	85.0	3.00	29.56
253.5	94.0	3.50	32.52
289.7	104.0	4.00	35.79
325.9	113.0	4.49	38.69
362.1	123.0	4.99	41.89
434.6	143.0	5.99	48.19
507.1	163.0	6.99	54.35
579.6	178.0	7.99	58.71
652.0	191.0	8.99	62.32
724.5	200.0	9.99	64.53
797.0	206.0	10.99	65.73
869.5	209.0	11.99	65.94
942.0	210.0	12.99	65.50
1014.5	211.0	13.99	65.06
1086.9	211.0	14.99	64.30
1159.5	210.0	15.99	63.24

PROJECT 851-1298

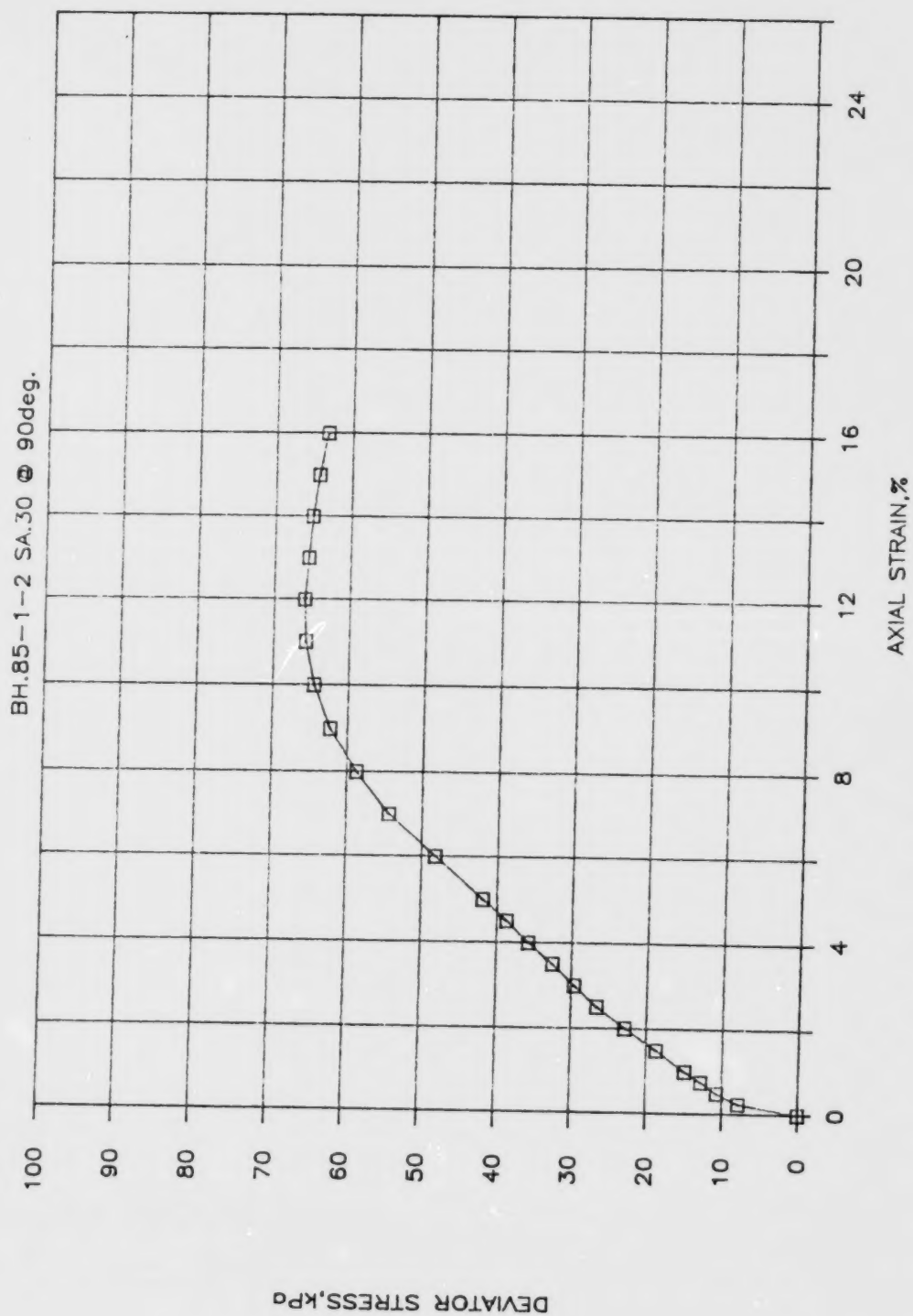
(GLAL PROJECT # 85-GT-4)

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UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 12-2



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UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 13-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-1-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	30	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	29.79	BH. 85-1-2 SA. 30 @ 45 deg.	

SAMPLE HEIGHT, cm	5.56	WET WEIGHT, gm	87.0
SAMPLE DIAMETER, cm	3.31	DRY WEIGHT, gm	61.1
SAMPLE AREA, cm ²	8.60	WATER CONTENT, %	41.8
SAMPLE VOLUME, cc	47.84	POROSITY, %	
UNIT WEIGHT, kN/m ³	17.82	DRY UNIT WT., kN/m ³	12.57

TEST RESULTS		LIQUID LIMIT, %	42
COMPRESS. STRESS, kPa	120.9	PLASTIC INDEX, %	24
STRAIN AT FAILURE, %	10.0	LAB. VANE, Peak, kPa	37.7
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	3.1

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
13.9	38.0	0.25	18.58
27.8	61.0	0.50	29.74
41.7	80.0	0.75	38.91
55.6	95.0	1.00	46.09
83.4	124.0	1.50	59.86
111.2	145.0	2.00	69.64
139.0	165.0	2.50	78.84
166.8	180.0	3.00	85.57
194.6	193.0	3.50	91.27
222.4	207.0	4.00	97.39
250.2	220.0	4.50	102.96
278.0	229.0	5.00	106.61
333.6	247.0	6.00	113.78
389.2	257.0	7.00	117.13
444.8	264.0	8.00	119.03
500.4	269.0	9.00	119.96
556.0	274.0	10.00	120.85
611.6	275.0	11.00	119.94
667.2	274.0	12.00	118.17

PROJECT 851-1298

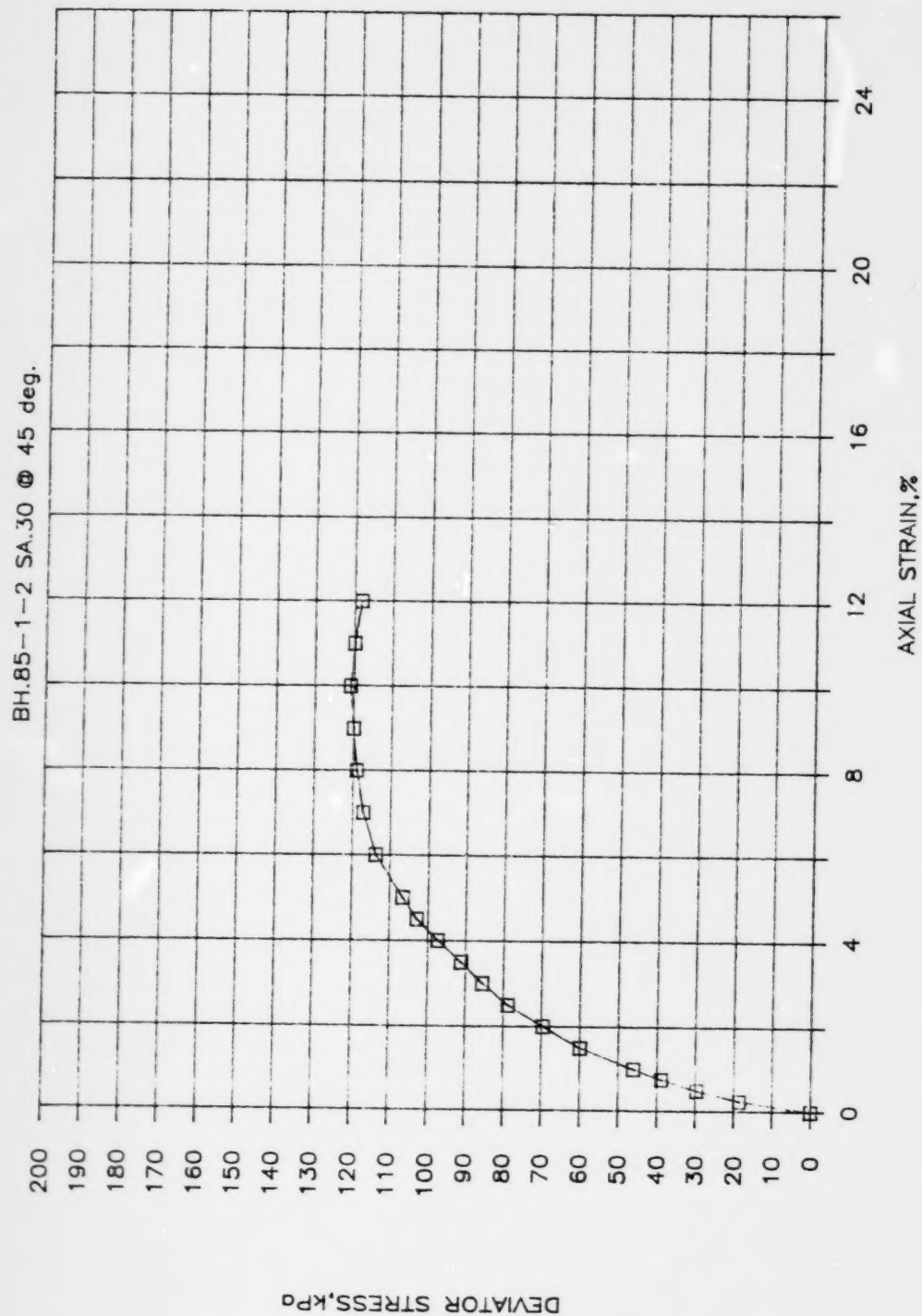
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UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 13-2



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UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 14-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-1-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	30	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	29.65	BH. 85-1-2 SA. 30 @ 0 deg.	

SAMPLE HEIGHT, cm	5.26	WET WEIGHT, gm	83.7
SAMPLE DIAMETER, cm	3.31	DRY WEIGHT, gm	59.8
SAMPLE AREA, cm ²	8.60	WATER CONTENT, %	39.6
SAMPLE VOLUME, cc	45.26	POROSITY, %	
UNIT WEIGHT, kN/m ³	18.13	DRY UNIT WT., kN/m ³	12.99

TEST RESULTS		LIQUID LIMIT, %	42
COMPRESS. STRESS, kPa	156.3	PLASTIC INDEX, %	24
STRAIN AT FAILURE, %	7.0	LAB. VANE, Peak, kPa	37.7
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	3.1

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
13.1	23.0	0.25	11.24
26.2	37.0	0.50	18.04
39.3	50.0	0.75	24.32
52.6	68.0	1.00	32.99
70.8	110.0	1.50	53.10
105.0	159.0	2.00	76.37
131.2	199.0	2.49	95.09
157.4	235.0	2.99	111.72
183.6	264.0	3.49	124.86
209.8	285.0	3.99	134.10
236.0	304.0	4.49	142.30
262.2	319.0	4.98	148.54
314.8	338.0	5.98	155.73
367.4	343.0	6.98	156.35
420.0	331.0	7.98	149.26

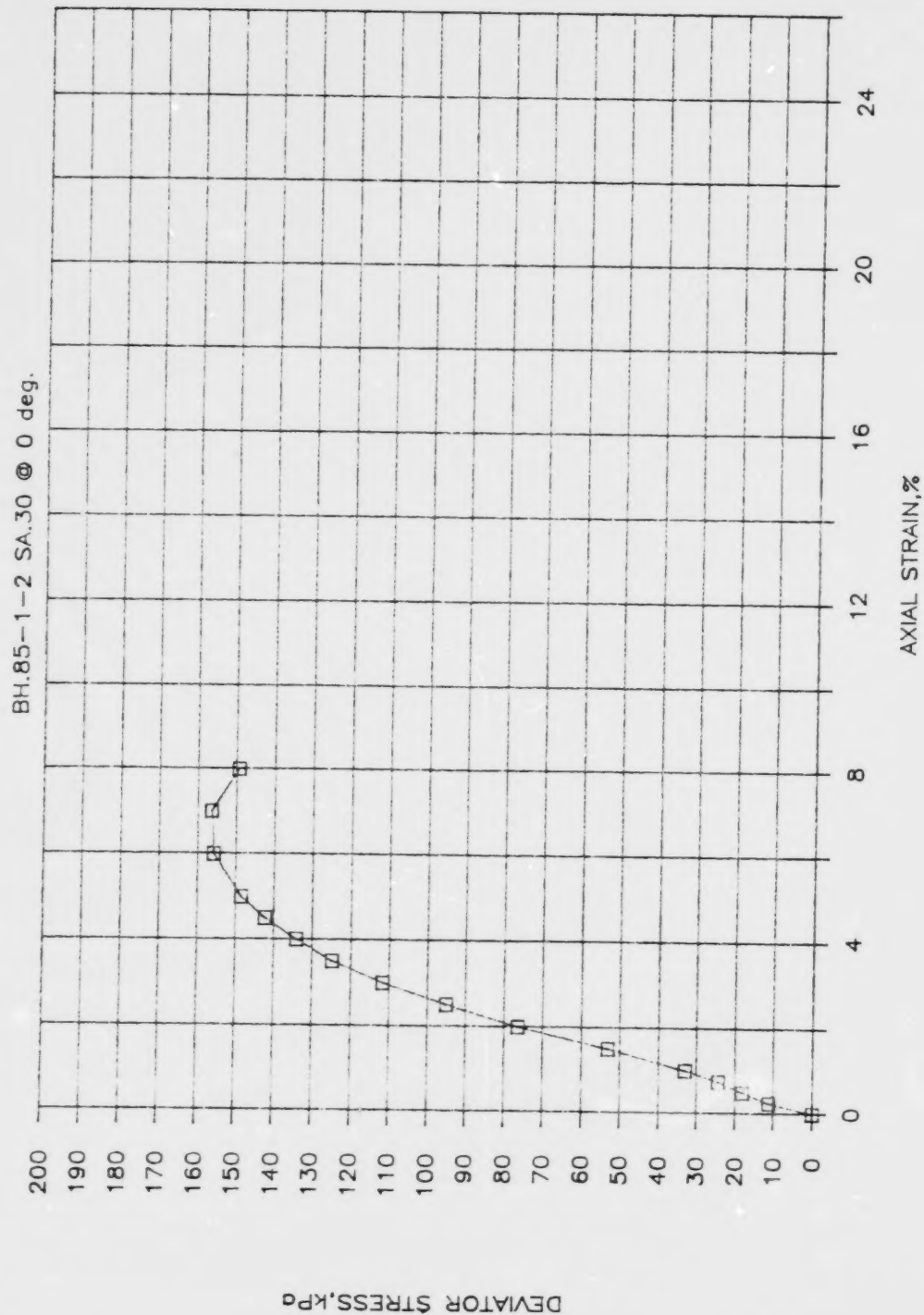
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

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UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 14-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 15-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	6	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	4.75	BH. 85-3-2 SA. 6 @ 90 deg.	
=====			
SAMPLE HEIGHT, cm	8.40	WET WEIGHT, gm	195.9
SAMPLE DIAMETER, cm	3.90	DRY WEIGHT, gm	151.9
SAMPLE AREA, cm ²	11.95	WATER CONTENT, %	28.8
SAMPLE VOLUME, cc	100.35	POROSITY, %	
UNIT WEIGHT, kN/m ³	19.14	DRY UNIT WT., kN/m ³	14.86
=====			
TEST RESULTS		LIQUID LIMIT, %	55
COMPRESS. STRESS, kPa	378.0	PLASTIC INDEX, %	29
STRAIN AT FAILURE, %	1.5	LAB. VANE, Peak, kPa	
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
21.0	165.0	0.25	58.10
42.0	365.0	0.50	128.20
63.0	584.0	0.75	204.61
84.0	808.0	1.00	282.38
126.0	1088.0	1.50	378.31
168.0	1070.0	2.00	370.16

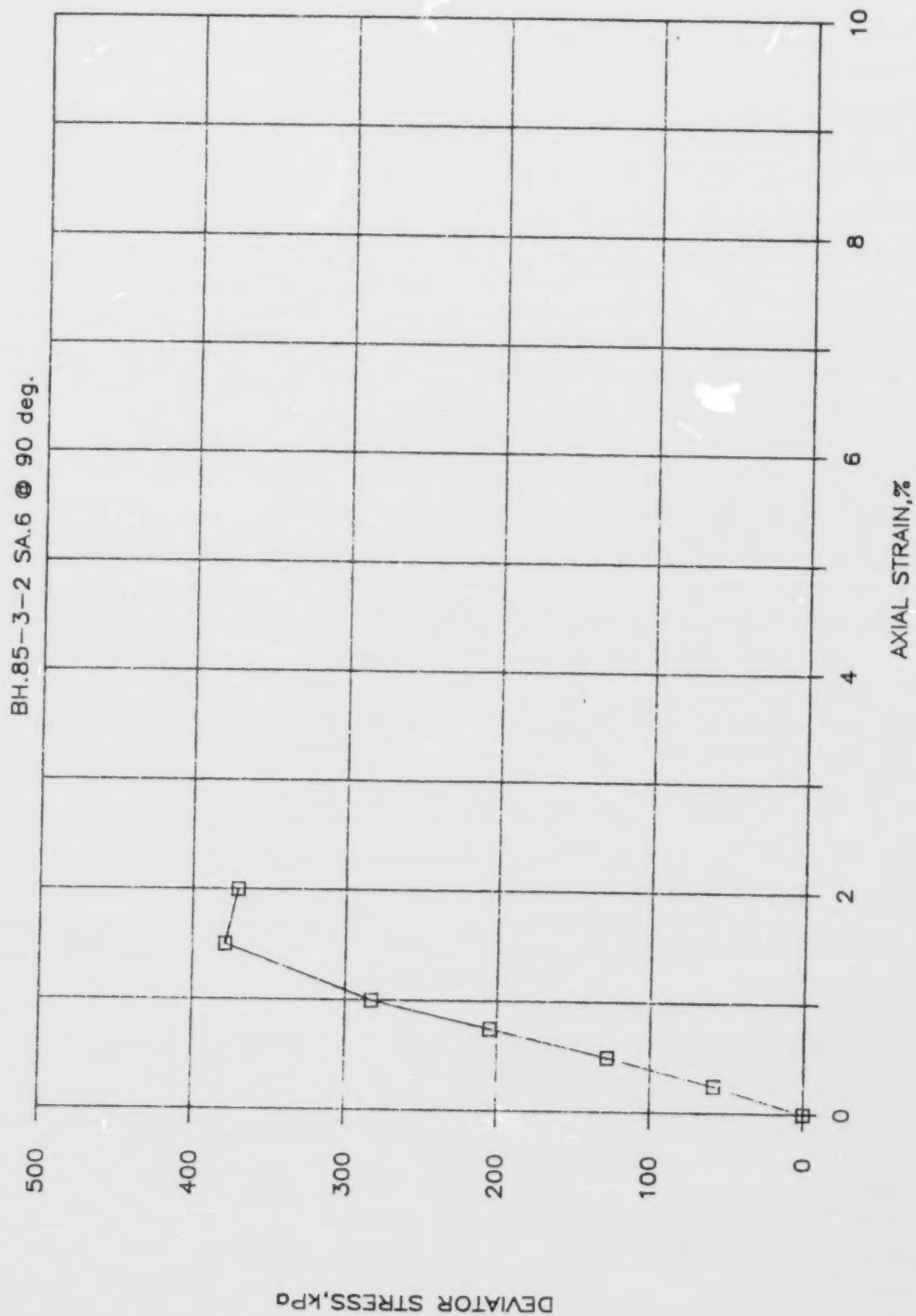
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

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UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 15-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 1 OF 2

FIGURE 16-1

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	6	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	4.73	BH. 85-3-2 SA. 6 @ 15 deg.	
SAMPLE HEIGHT, cm	5.81	WET WEIGHT, gm	98.0
SAMPLE DIAMETER, cm	3.31	DRY WEIGHT, gm	76.3
SAMPLE AREA, cm ²	8.60	WATER CONTENT, %	28.3
SAMPLE VOLUME, cc	49.99	POROSITY, %	
UNIT WEIGHT, kN/m ³	19.22	DRY UNIT WT., kN/m ³	14.98
TEST RESULTS		LIQUID LIMIT, %	55
COMPRESS. STRESS, kPa	303.6	PLASTIC INDEX, %	29
STRAIN AT FAILURE, %	6.0	LAB. VANE, Peak, kPa	
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
14.5	43.0	0.25	21.02
29.0	95.0	0.50	46.32
43.5	148.0	0.75	71.99
58.1	200.0	1.00	97.03
87.1	310.0	1.50	149.64
116.1	398.0	2.00	191.15
145.1	470.0	2.50	224.58
174.1	527.0	3.00	250.53
203.1	568.0	3.50	268.63
232.1	600.0	3.99	282.30
261.1	623.0	4.49	291.59
290.1	643.0	4.99	299.38
348.2	659.0	5.99	303.60
406.3	660.0	6.99	300.83
464.4	600.0	7.99	270.54

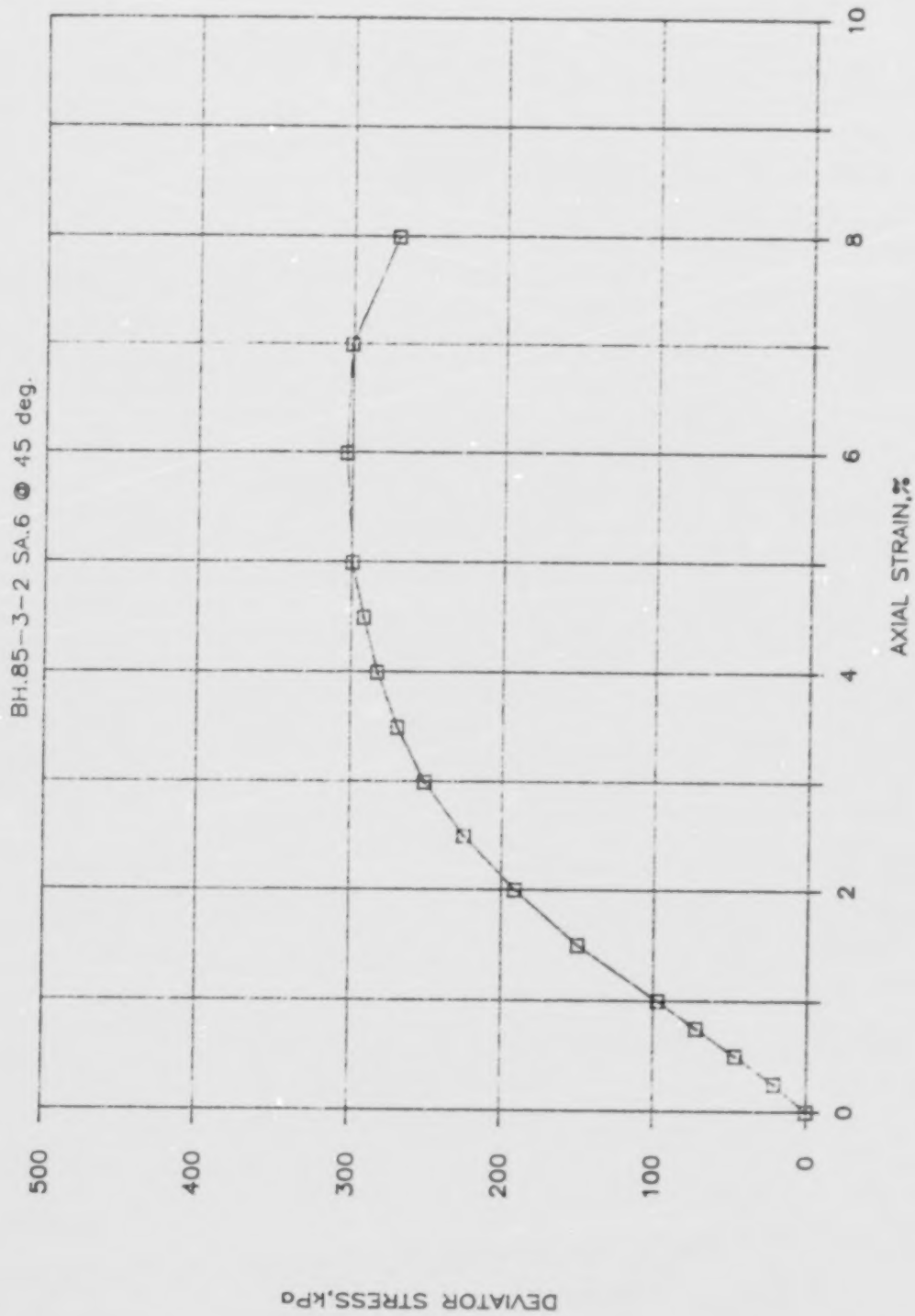
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

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UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 16-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 1 OF 2

FIGURE 17-1

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	951-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	6	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	4.70	BH. 85-3-2 SA. 6 @ 0 deg.	
=====			
SAMPLE HEIGHT, cm	5.48	WET WEIGHT, gm	91.1
SAMPLE DIAMETER, cm	3.31	DRY WEIGHT, gm	70.7
SAMPLE AREA, cm ²	8.60	WATER CONTENT, %	28.5
SAMPLE VOLUME, cc	47.15	POROSITY, %	
UNIT WEIGHT, kN/m ³	18.94	DRY UNIT WT., kN/m ³	14.74
=====			
TEST RESULTS		LIQUID LIMIT, %	55
COMPRESSION STRESS, kPa	268.9	PLASTIC INDEX, %	29
STRAIN AT FAILURE, %	4.5	LAB. VANE, Peak, kPa	
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid, kPa	

Strain	Load	Axial	Deviator
Dial	Dial	Strain	Stress
mm	mm	%	kPa
0.0	0.0	0	0.00
11.7	50.0	0.25	29.33
17.4	100.0	0.50	48.76
41.1	152.0	0.75	73.93
54.8	215.0	1.00	104.31
82.2	330.0	1.50	159.30
109.6	430.0	2.00	206.51
137.8	495.0	2.50	236.52
164.4	530.0	3.00	255.75
191.9	563.0	3.50	266.25
219.2	575.0	4.00	269.58
246.6	574.5	4.50	268.87
274.0	572.0	5.00	266.30

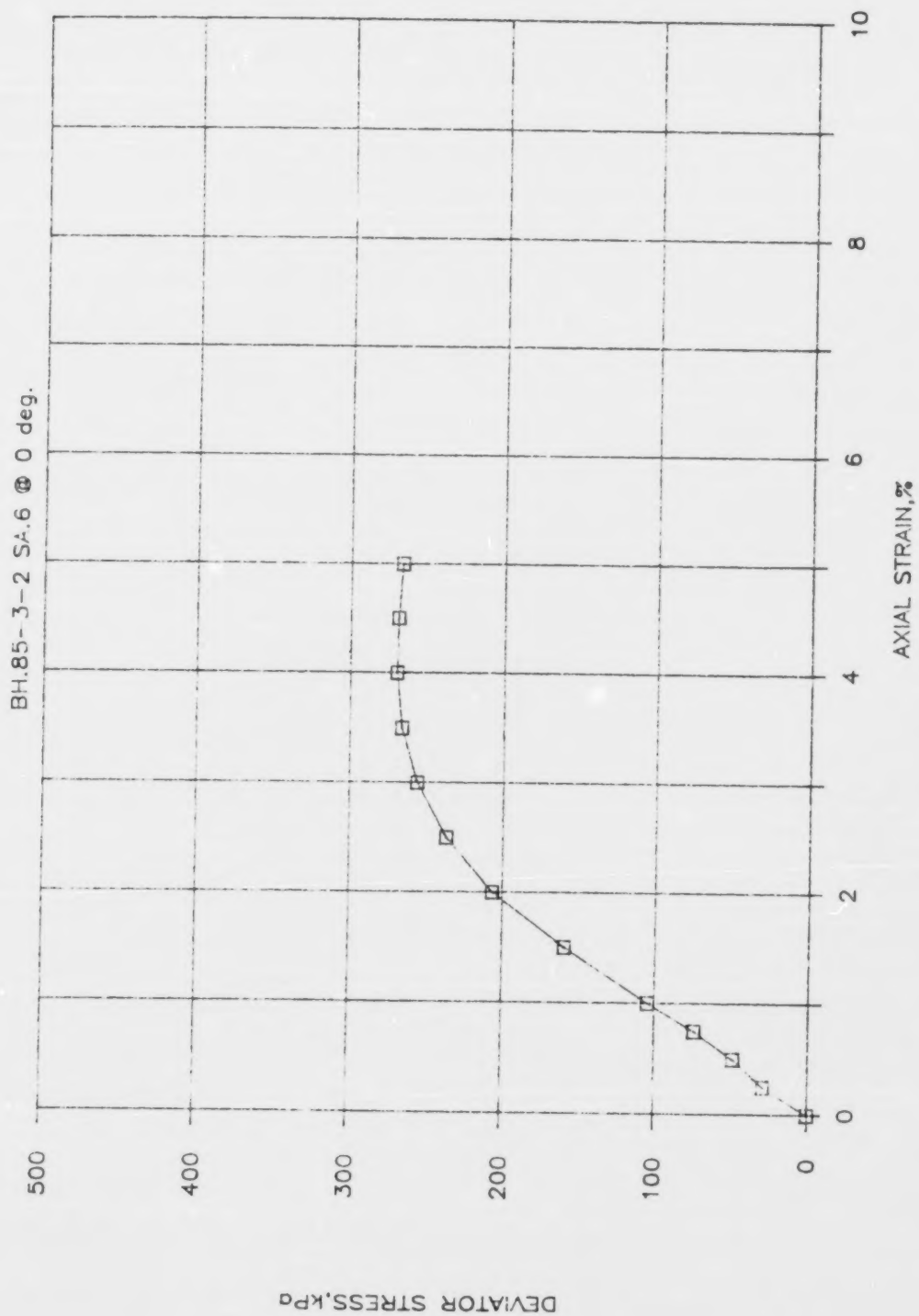
PROJECT 951-1298 (GLAL PROJECT # 85-GT-4)

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UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 17-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 18-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

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=====
PROJECT NUMBER      851-1298  PROVING RING,kg/mm div.      0.043
BOREHOLE NUMBER     85-3-2    STRAIN RATE mm/min          0.2032
SAMPLE NUMBER       11        SPECIFIC GRAVITY,assumed     2.78
SAMPLE DEPTH,m      12.35    BH.85-3-2 SA.11 @ 90 deg.
=====
SAMPLE HEIGHT,cm    8.62          WET WEIGHT,gm              205.5
SAMPLE DIAMETER,cm  3.79          DRY WEIGHT,gm              167.9
SAMPLE AREA,cm2     11.28         WATER CONTENT,%            22.3
SAMPLE VOLUME,cc     97.25         POROSITY,%                 22.3
UNIT WEIGHT,kN/m3    20.72         DRY UNIT WT.,kN/m3         16.94
=====
TEST RESULTS
COMPRESS.STRESS,kPa  153.7         LIQUID LIMIT,%             34
STRAIN AT FAILURE,%  8.0           PLASTIC INDEX,%            16
CELL PRESSURE,kPa    0.0           LAB. VANE,Peak,kPa
LAB. VANE,Resid,kPa
=====

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=====
Strain      Load      Axial      Deviator
Dial        Dial        Strain      Stress
mm          mm          %           kPa
=====
0.0         0.0         0           0.00
21.6        53.0        0.25       19.76
43.2        79.0        0.50       29.38
64.8        101.0       0.75       37.47
86.2        125.0       1.00       46.26
129.4       168.0       1.50       61.85
172.6       217.0       2.00       79.49
215.8       273.0       2.50       99.49
259.0       310.0       3.00       112.39
302.2       346.0       3.51       124.80
345.4       374.0       4.01       134.20
388.6       395.0       4.51       140.99
431.8       409.0       5.01       145.22
518.0       430.0       6.01       151.07
604.2       442.0       7.01       153.64
690.4       447.0       8.01       153.70
777.6       448.0       9.02       152.35
862.8       448.0       10.01      150.70
949.0       444.0       11.01      147.69
=====

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PROJECT 851-1298

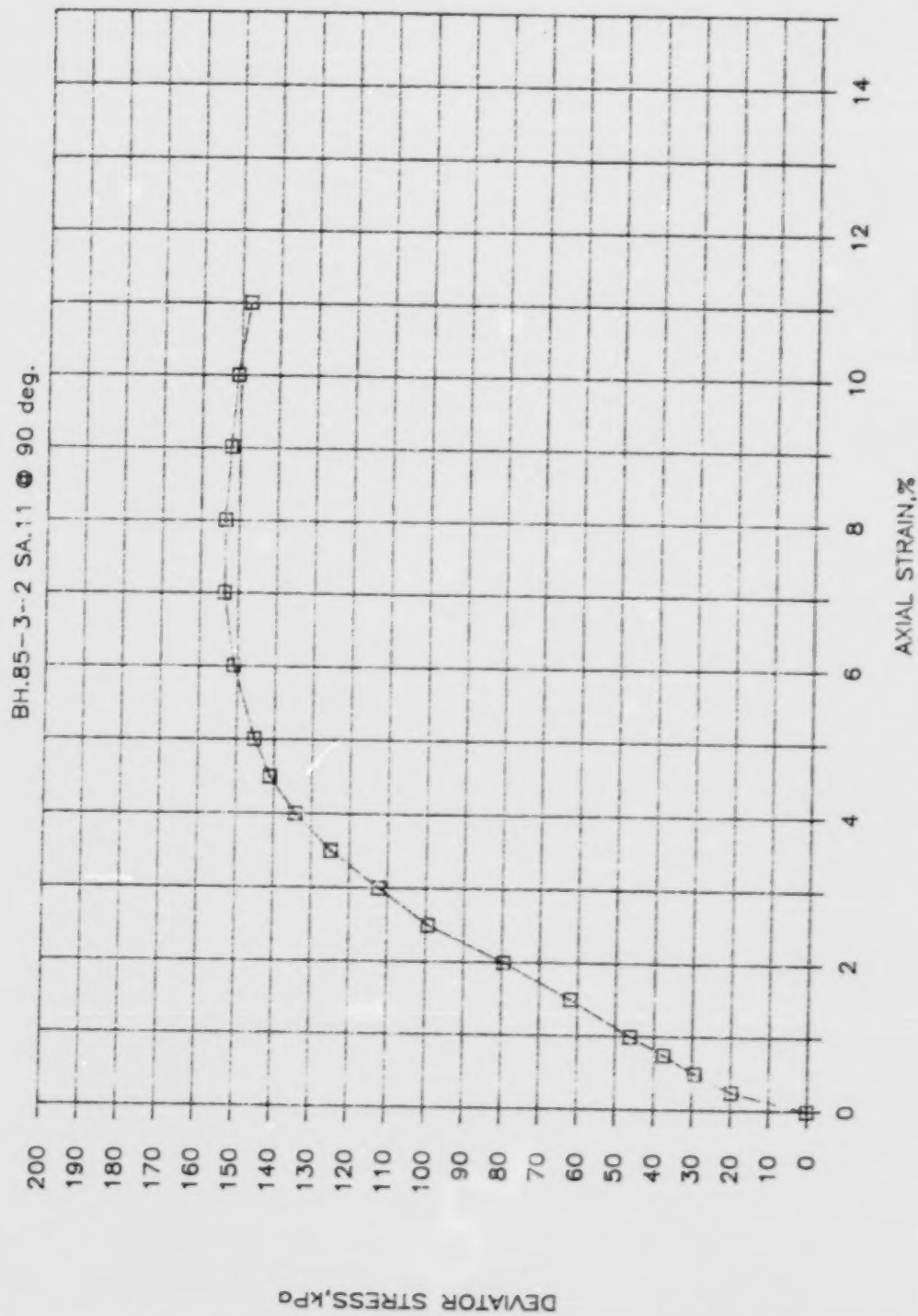
(GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 18-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 1 OF 2

FIGURE 19-1

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	11	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	12.33	BH. 85-3-2 SA. 11 @ 45 deg.	

SAMPLE HEIGHT, cm	5.36	WET WEIGHT, gm	95.2
SAMPLE DIAMETER, cm	3.31	DRY WEIGHT, gm	79.0
SAMPLE AREA, cm ²	8.60	WATER CONTENT, %	21.8
SAMPLE VOLUME, cc	46.12	POROSITY, %	
UNIT WEIGHT, kN/m ³	20.23	DRY UNIT WT., kN/m ³	16.61

TEST RESULTS		LIQUID LIMIT, %	74
COMPRESS. STRESS, kPa	182.7	PLASTIC INDEX, %	16
STRAIN AT FAILURE, %	20.0	LAB. VANE, Peak, kPa	
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
13.4	28.0	0.25	13.69
26.8	44.0	0.50	21.46
40.2	61.0	0.75	29.67
53.6	77.0	1.00	37.36
60.4	111.0	1.50	53.58
107.2	144.0	2.00	69.16
134.0	172.0	2.50	82.18
160.8	195.0	3.00	92.70
187.6	215.0	3.50	101.68
214.4	234.0	4.00	110.09
241.2	252.0	4.50	117.94
268.0	266.0	5.00	123.84
321.6	293.0	6.00	134.97
375.2	315.0	7.00	143.57
428.0	336.0	8.00	151.49
482.4	354.0	9.00	157.87
536.0	370.0	10.00	163.19
589.6	386.0	11.00	168.36
643.2	400.0	12.00	172.50
696.8	413.0	13.00	176.00
750.4	423.0	14.00	178.28
804.0	432.0	15.00	179.95
857.6	440.0	16.00	181.13
911.2	448.0	17.00	182.23
964.8	454.0	18.00	182.44
1018.4	460.0	19.00	182.68
1072.0	466.0	20.00	182.70

PROJECT 851-1298

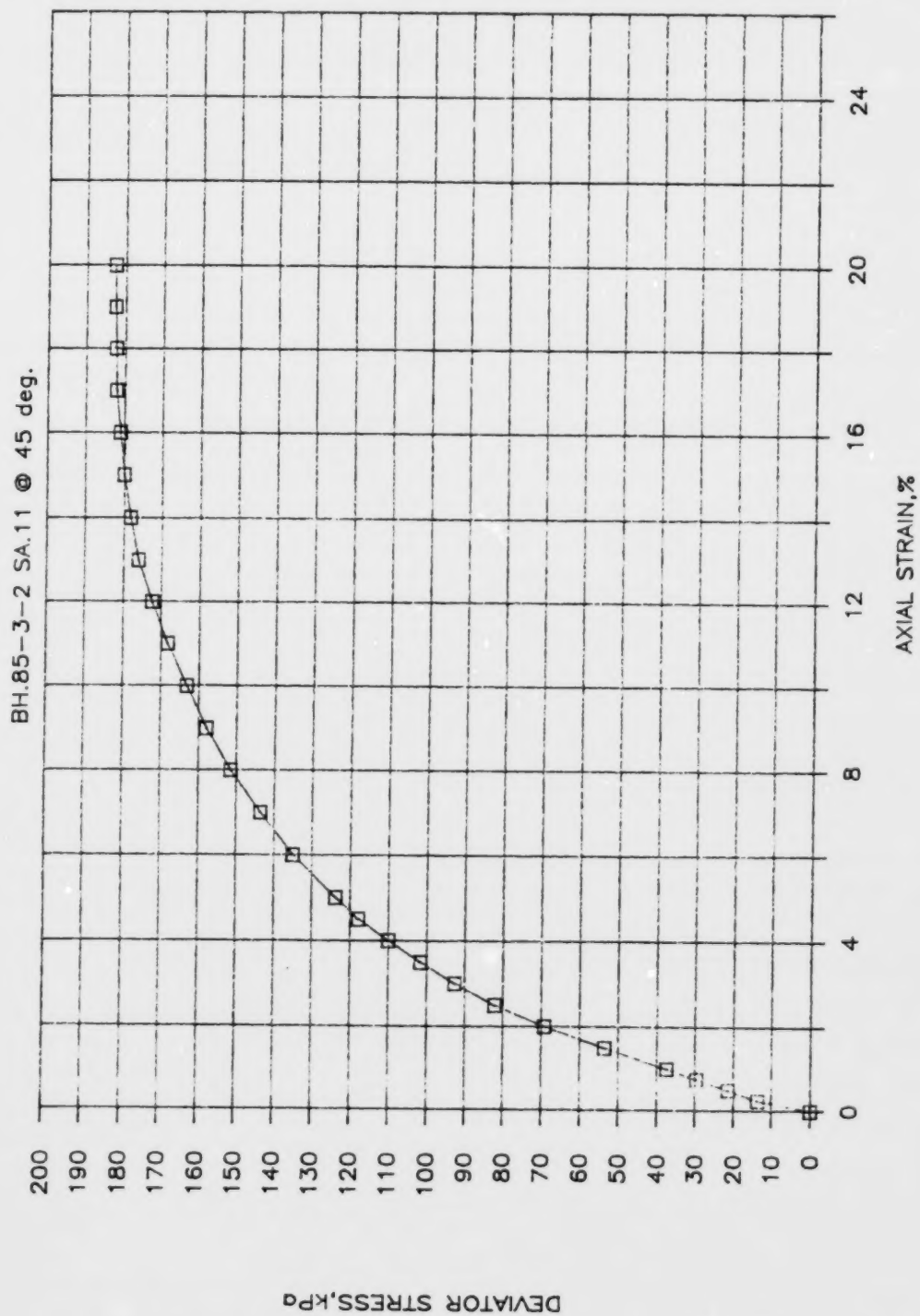
(GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 19-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 20-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	11	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	12.29	BH. 85-3-2 SA. 11 @ 0 deg.	
SAMPLE HEIGHT, cm	5.44	WET WEIGHT, gm	97.2
SAMPLE DIAMETER, cm	3.31	DRY WEIGHT, gm	79.3
SAMPLE AREA, cm ²	8.60	WATER CONTENT, %	22.3
SAMPLE VOLUME, cc	46.81	POROSITY, %	
UNIT WEIGHT, kN/m ³	20.36	DRY UNIT WT., kN/m ³	16.55
TEST RESULTS		LIQUID LIMIT, %	34
COMPRESS. STRESS, kPa	178.3	PLASTIC INDEX, %	16
STRAIN AT FAILURE, %	15.0	LAB. VANE, Peak, kPa	
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
13.6	53.0	0.25	25.91
27.2	77.0	0.50	37.55
40.8	96.0	0.75	46.69
54.4	118.0	1.00	57.25
81.6	159.0	1.50	76.75
108.8	199.0	2.00	95.57
136.0	219.0	2.50	104.64
163.2	240.0	3.00	114.89
190.4	262.0	3.50	123.90
217.6	280.0	4.00	131.73
244.8	308.0	4.50	144.15
272.0	318.0	5.00	148.05
326.4	339.0	6.00	156.17
380.8	360.0	7.00	164.07
435.2	377.0	8.00	169.98
489.6	387.0	9.00	172.59
544.0	396.0	10.00	174.66
598.4	408.0	11.00	177.95
652.8	413.0	12.00	178.11
707.2	417.0	13.00	177.70
761.6	423.0	14.00	178.28
816.0	428.0	15.00	178.29
870.4	433.0	16.00	178.25
924.8	435.0	17.00	176.94
979.2	436.0	18.00	175.21
1033.6	435.0	19.00	172.68

PROJECT 851-1298

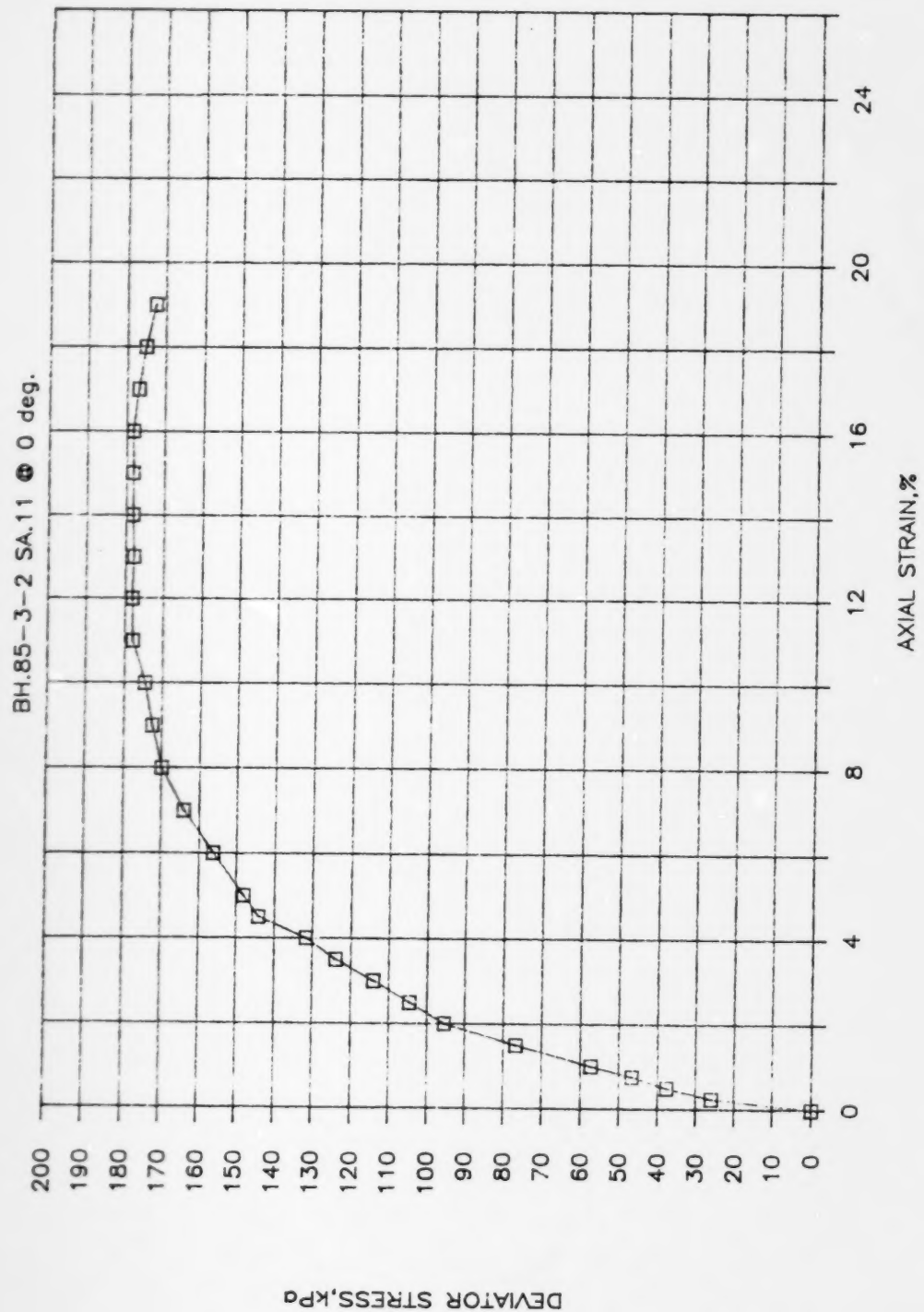
(GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 20-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 21-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	BS-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	15	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	18.76	BH. BS-3-2 SA. 15 @ 90 deg.	
SAMPLE HEIGHT, cm	8.61	WET WEIGHT, gm	211.5
SAMPLE DIAMETER, cm	3.73	DRY WEIGHT, gm	172.9
SAMPLE AREA, cm ²	10.93	WATER CONTENT, %	22.2
SAMPLE VOLUME, cc	94.08	POROSITY, %	
UNIT WEIGHT, kN/m ³	22.04	DRY UNIT WT., kN/m ³	18.03
TEST RESULTS			
COMPRESS. STRESS, kPa	111.1	LIQUID LIMIT, %	31
STRAIN AT FAILURE, %	10.0	PLASTIC INDEX, %	14
CELL PRESSURE, kPa	0.0	LAB. VANE, Peak, kPa	64.9
		LAB. VANE, Resid. kPa	4.0

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
21.5	45.0	0.25	17.32
43.0	62.0	0.50	23.81
64.5	76.0	0.75	29.11
86.1	90.0	1.00	34.39
129.1	120.0	1.50	45.62
172.1	148.0	2.00	55.97
215.1	175.0	2.50	65.85
258.1	196.0	3.00	73.37
301.1	218.0	3.50	81.19
344.1	238.0	4.00	88.18
387.1	255.0	4.50	93.98
430.1	266.0	5.00	97.53
516.2	286.0	5.99	103.76
602.3	300.0	7.00	107.68
688.4	309.0	8.00	109.71
774.5	315.0	8.99	110.63
860.6	320.0	10.00	111.15
946.7	324.0	11.00	111.29
1032.8	324.0	11.99	110.04
1118.9	322.0	13.00	108.12

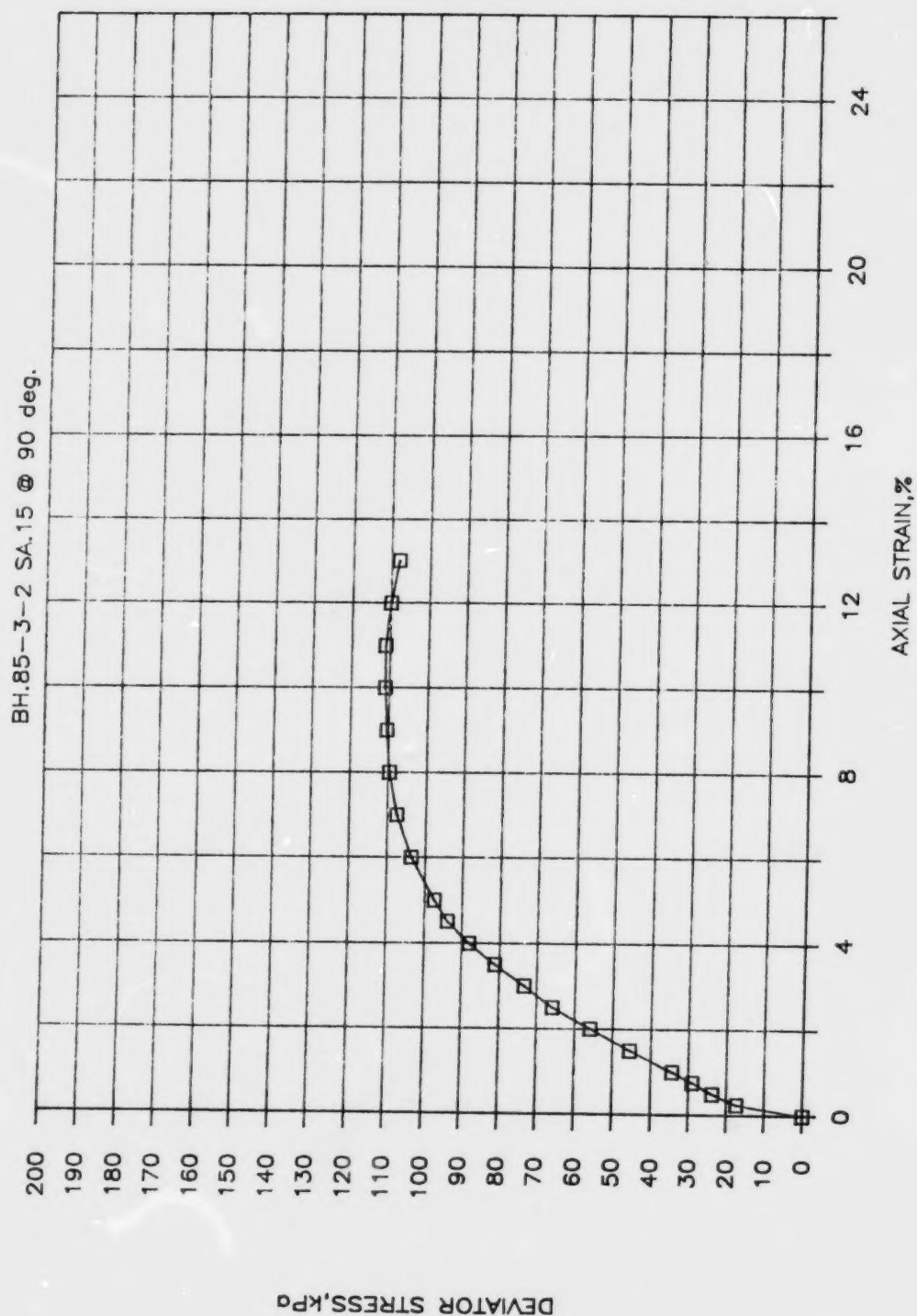
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 21-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 22-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	15	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	18.68	BH. 85-3-2 SA. 15 @ 45 deg.	

SAMPLE HEIGHT, cm	5.47	WET WEIGHT, gm	94.3
SAMPLE DIAMETER, cm	3.28	DRY WEIGHT, gm	77.3
SAMPLE AREA, cm ²	8.04	WATER CONTENT, %	21.7
SAMPLE VOLUME, cc	43.99	POROSITY, %	
UNIT WEIGHT, kN/m ³	21.02	DRY UNIT WT., kN/m ³	17.27

TEST RESULTS		LIQUID LIMIT, %	31
COMPRESS. STRESS, kPa	145.6	PLASTIC INDEX, %	14
STRAIN AT FAILURE, %	8.0	LAB. VANE, Peak, kPa	64.9
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	4.0

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
13.7	83.0	0.25	43.41
27.4	118.0	0.50	61.56
41.1	150.0	0.75	78.06
54.7	180.0	1.00	93.44
82.1	220.0	1.50	113.62
109.5	241.0	2.00	123.84
136.9	254.0	2.50	129.85
164.3	264.0	3.00	134.27
191.7	271.0	3.50	137.12
219.1	277.0	4.01	139.42
246.5	281.0	4.51	140.70
273.9	285.0	5.01	141.95
328.6	292.0	6.01	143.91
383.3	298.0	7.01	145.30
438.0	302.0	8.01	145.67
492.7	304.0	9.01	145.04
547.4	305.5	10.01	144.16
602.1	306.0	11.01	142.79
656.8	306.5	12.01	141.41
711.5	307.0	13.01	139.13
766.2	309.0	14.01	137.33
820.9	310.0	15.01	135.15
875.6	311.0	16.01	132.10
930.3	314.3	17.01	136.77
985.0	317.0	18.01	136.28
1039.7	320.0	19.01	135.90
1094.4	322.0	20.01	135.26

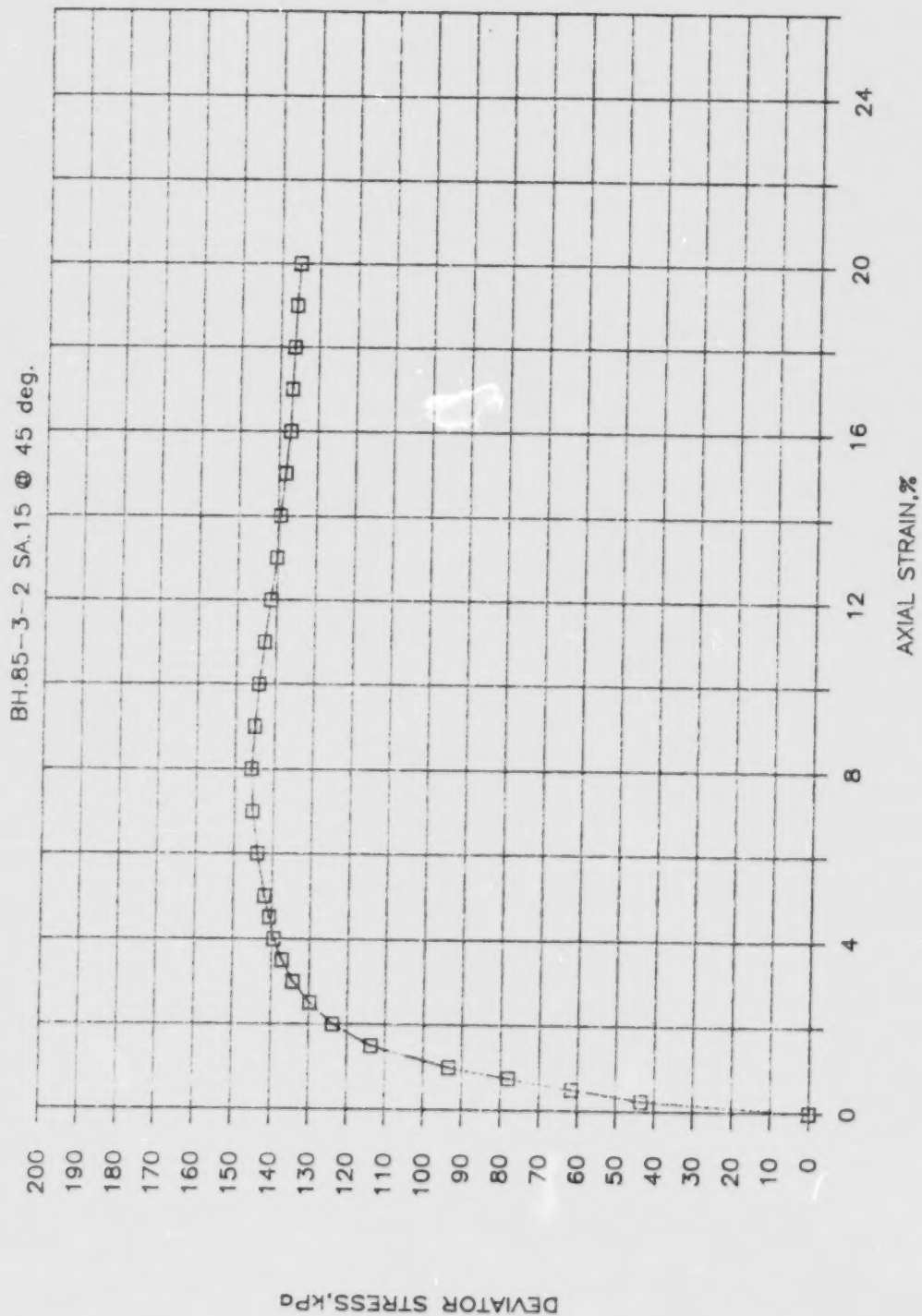
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 22-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 23-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	15	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	18.70	BH. 85-3-2 SA. 15 @ 0 deg.	

SAMPLE HEIGHT, cm	6.30	WET WEIGHT, gm	149.3
SAMPLE DIAMETER, cm	3.74	DRY WEIGHT, gm	121.9
SAMPLE AREA, cm ²	10.99	WATER CONTENT, %	22.3
SAMPLE VOLUME, cc	69.21	POROSITY, %	
UNIT WEIGHT, kN/m ³	21.15	DRY UNIT WT., kN/m ³	17.30

TEST RESULTS		LIQUID LIMIT, %	31
COMPRESS. STRESS, kPa	119.7	PLASTIC INDEX, %	14
STRAIN AT FAILURE, %	19.0	LAB. VANE, Peak, kPa	64.9
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid, kPa	4.0

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
15.7	37.0	0.25	14.17
31.4	46.0	0.50	17.57
47.1	53.0	0.75	20.19
63.0	62.0	1.00	23.56
78.4	79.0	1.50	29.87
125.8	95.0	2.00	35.74
157.2	113.0	2.50	42.29
188.6	129.0	2.99	48.03
220.0	146.0	3.49	54.09
251.4	161.0	3.99	59.33
282.8	176.0	4.49	64.53
314.2	189.0	4.99	68.93
377.2	215.0	5.99	77.59
440.2	240.0	6.99	85.69
503.2	263.0	7.99	92.89
566.2	282.0	8.99	98.52
629.2	300.0	9.99	103.66
692.2	315.0	10.99	107.63
755.2	328.0	11.99	110.91
818.2	340.0	12.99	113.56
881.2	351.0	13.99	115.89
944.2	361.0	14.99	117.80
1007.2	370.0	15.99	119.32
1070.2	375.0	16.99	119.49
1133.2	380.0	17.99	119.63
1196.2	385.0	18.99	119.72
1259.2	387.0	19.99	118.86

PROJECT 851-1298

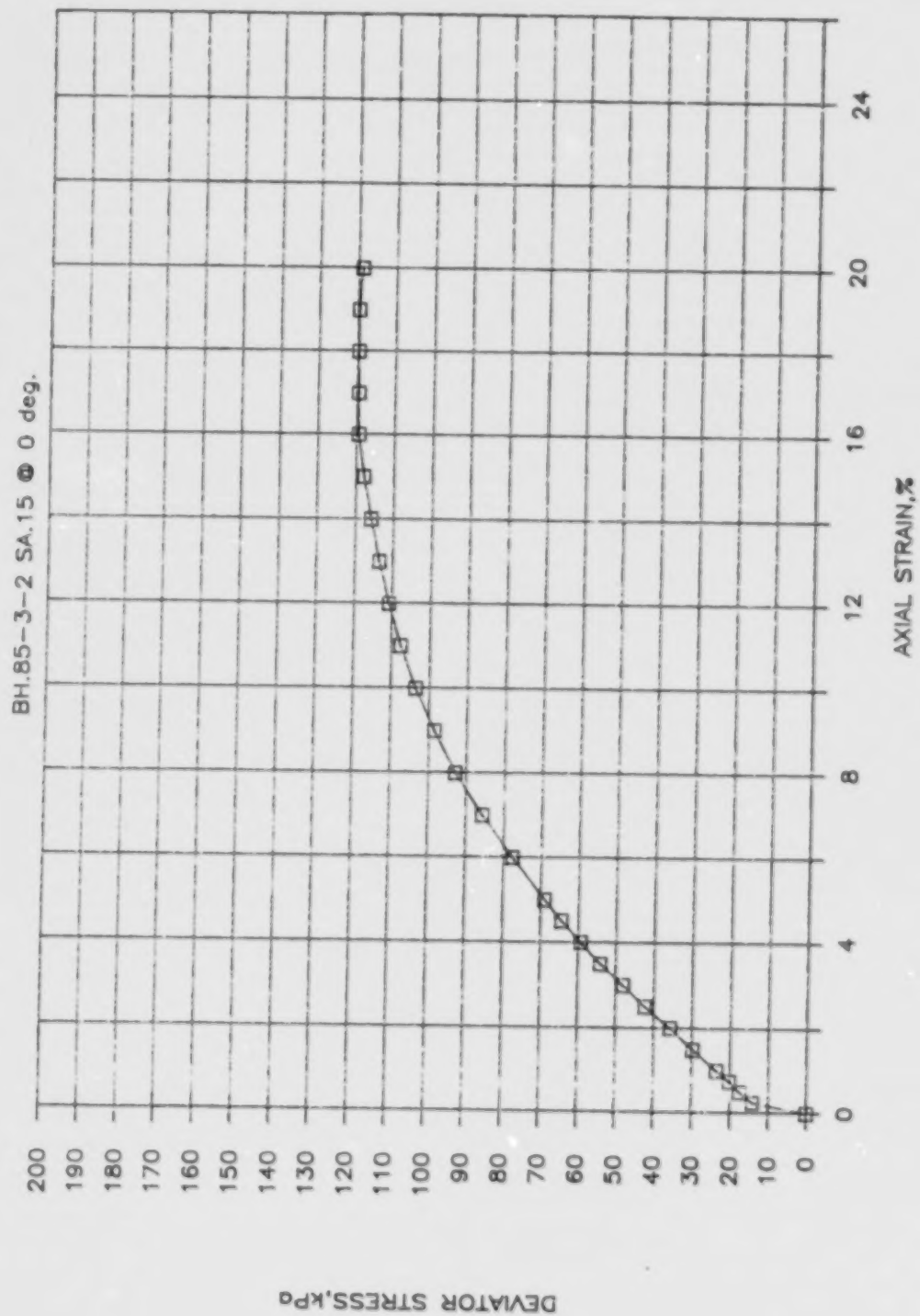
(GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 23-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 1 OF 2

FIGURE 24-1

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	951-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	19	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	24.85	BH. 85-3-2 SA. 19 @ 90 deg.	

SAMPLE HEIGHT, cm	9.14	WET WEIGHT, gm	187.2
SAMPLE DIAMETER, cm	3.90	DRY WEIGHT, gm	147.0
SAMPLE AREA, cm ²	11.34	WATER CONTENT, %	27.4
SAMPLE VOLUME, cc	92.32	POROSITY, %	
UNIT WEIGHT, kN/m ³	19.88	DRY UNIT WT., kN/m ³	15.60

TEST RESULTS		LIQUID LIMIT, %	37
COMPRESS. STRESS, kPa	128.6	PLASTIC INDEX, %	16
STRAIN AT FAILURE, %	9.0	LAB. VANE, Peak, kPa	
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid, kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
20.3	41.0	0.25	15.21
40.6	60.0	0.50	22.20
60.9	78.0	0.85	28.76
81.4	95.0	1.00	34.97
102.0	125.0	1.50	45.78
162.6	154.0	2.00	56.12
203.2	183.0	2.50	66.35
243.8	211.0	3.00	76.11
284.4	240.0	3.49	86.12
325.0	268.2	3.99	95.67
365.6	290.0	4.49	102.99
406.2	308.0	4.99	108.81
487.5	344.0	5.99	120.25
569.0	360.0	6.99	124.50
650.4	373.0	7.99	127.61
731.8	380.0	8.99	128.59
813.2	382.0	9.99	127.85
894.6	381.5	10.99	126.26
976.0	378.0	11.99	123.70

PROJECT 951-1298

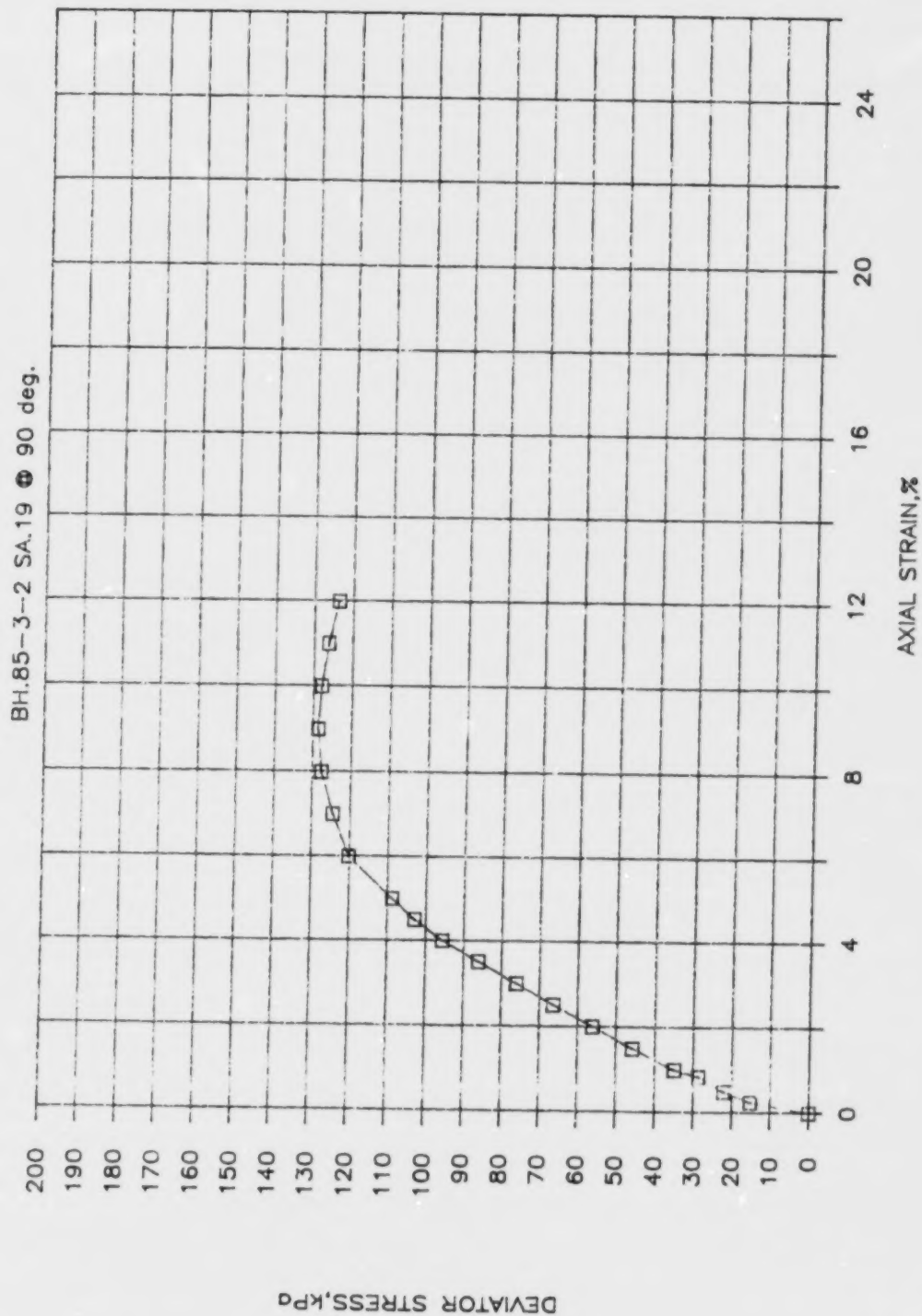
(GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 24-2



UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 25-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.243
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	19	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	24.75	BH. 85-3-2 SA. 19 @ 45 deg.	
SAMPLE HEIGHT, cm	5.01	WET WEIGHT, gm	81.7
SAMPLE DIAMETER, cm	3.78	DRY WEIGHT, gm	61.7
SAMPLE AREA, cm ²	11.22	WATER CONTENT, %	31.8
SAMPLE VOLUME, cc	56.22	POROSITY, %	
UNIT WEIGHT, kN/m ³	14.25	DRY UNIT WT., kN/m ³	10.81
TEST RESULTS			
COMPRESS. STRESS, kPa	80.3	LIQUID LIMIT, %	37
STRAIN AT FAILURE, %	7.1	PLASTIC INDEX, %	16
CELL PRESSURE, kPa	0.0	LAB. VANE, Peak, kPa	
		LAB. VANE, Resid. kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
12.7	44.0	0.25	16.49
25.4	59.0	0.51	22.06
38.1	74.0	0.76	27.60
50.9	86.0	1.02	31.99
76.3	111.0	1.52	41.08
101.7	134.0	2.03	49.33
127.1	154.0	2.54	56.40
152.5	172.0	3.04	62.67
177.9	184.0	3.55	66.69
203.3	193.0	4.06	69.58
228.7	203.0	4.56	72.80
254.1	211.0	5.07	75.27
280.0	223.0	5.89	78.70
355.9	230.0	7.10	80.29
406.8	232.0	8.12	80.10
457.7	228.0	9.14	77.85
508.6	222.0	10.15	74.95

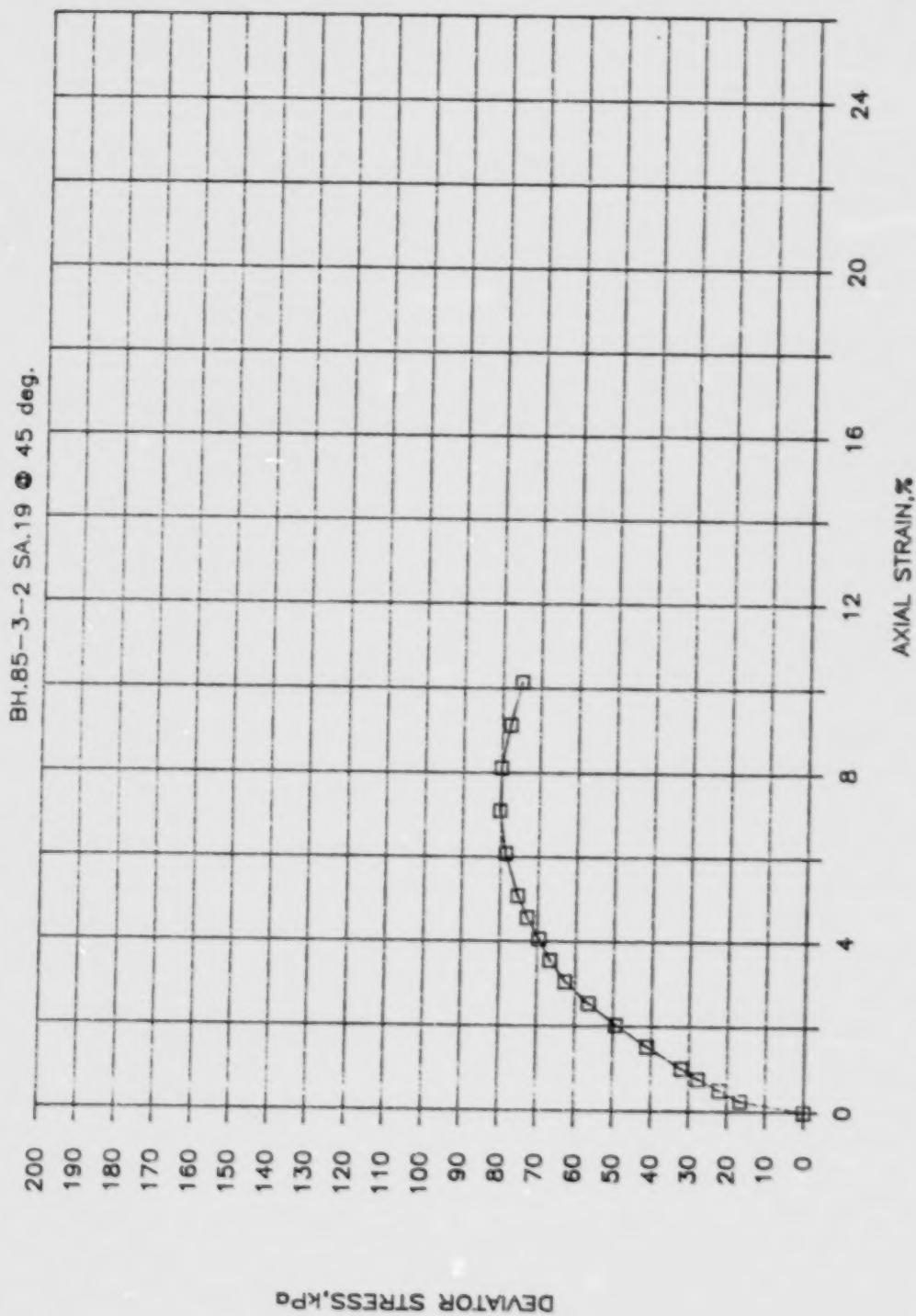
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 25-2



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 1 OF 2

FIGURE 26-1

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	85-3-2	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	19	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	24.65	BH. 85-3-2 SA. 19 @ 0 deg.	

SAMPLE HEIGHT, cm	5.46	WET WEIGHT, gm	92.4
SAMPLE DIAMETER, cm	3.36	DRY WEIGHT, gm	72.7
SAMPLE AREA, cm ²	8.87	WATER CONTENT, %	26.8
SAMPLE VOLUME, cc	48.41	POROSITY, %	
UNIT WEIGHT, kN/m ³	18.72	DRY UNIT WT., kN/m ³	14.76

TEST RESULTS		LIQUID LIMIT, %	37
COMPRESS. STRESS, kPa	123.6	PLASTIC INDEX, %	16
STRAIN AT FAILURE, %	14.0	LAB. VANE, Peak, kPa	
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
13.6	38.0	0.25	18.03
27.2	55.0	0.50	26.03
40.8	70.0	0.75	33.04
54.6	86.0	1.00	40.49
81.6	110.0	1.49	51.53
108.8	133.0	1.99	61.99
136.0	152.0	2.49	70.49
163.2	167.0	2.99	77.05
190.4	180.0	3.49	82.62
217.6	191.0	3.98	87.22
244.8	200.0	4.48	90.85
272.0	210.0	4.98	94.90
326.4	227.0	5.98	101.51
380.8	241.0	6.97	106.62
435.2	254.0	7.97	111.17
489.6	268.0	8.97	116.03
546.0	278.0	10.00	118.99
598.4	286.0	10.96	121.11
652.8	292.0	11.96	122.27
707.2	298.0	12.95	123.37
761.6	302.0	13.95	123.59
816.0	305.0	14.94	123.38
870.4	307.0	15.94	122.73
924.8	307.0	16.94	121.28
979.2	308.5	17.93	120.41
1033.6	308.5	18.93	118.95
1088.0	308.5	19.93	117.48

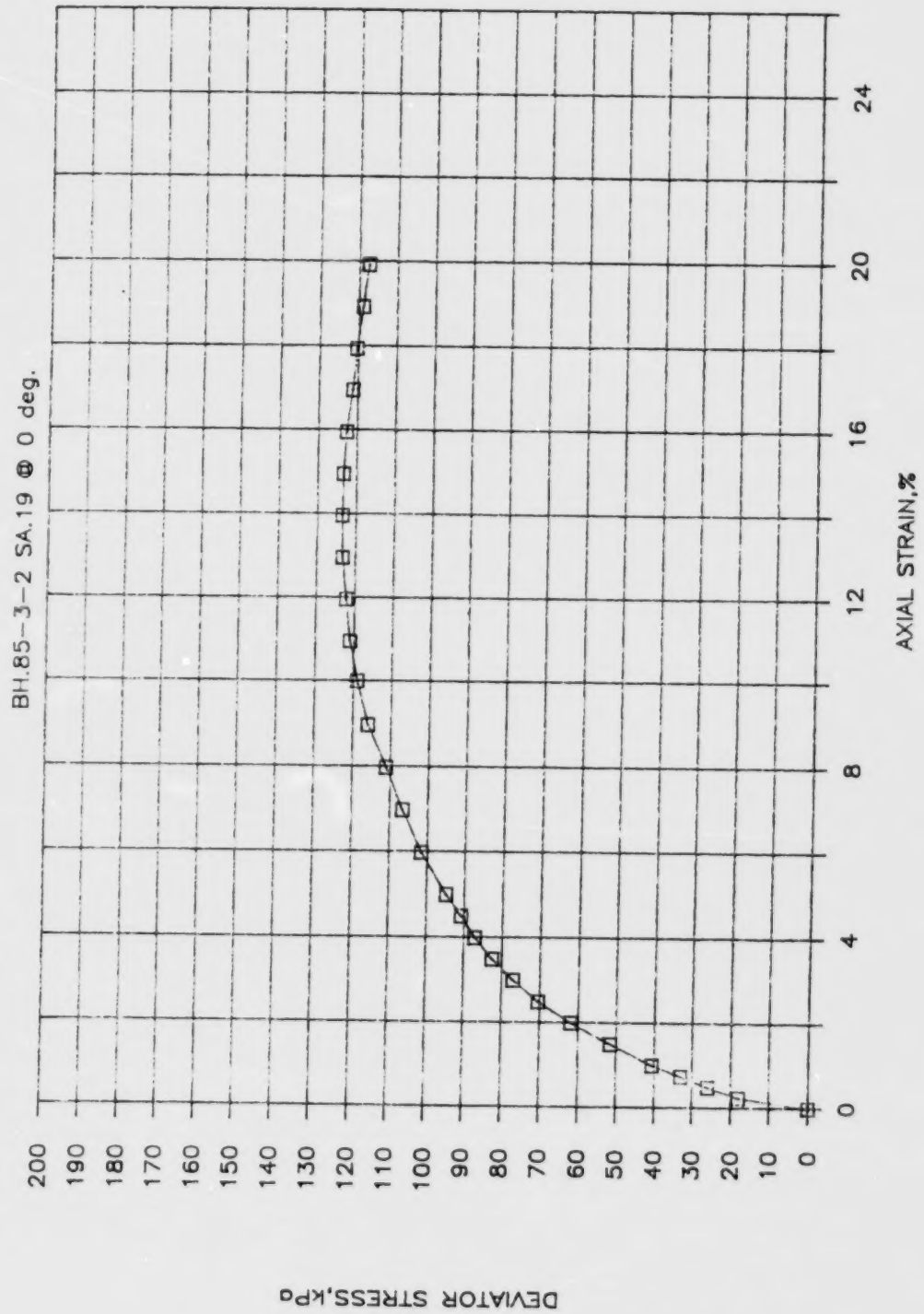
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 26-2



UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 27-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	1 3 5	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	7 5 6	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	UPPER TILL	PROCTOR COMPOSITE SAMPLE - A	

SAMPLE HEIGHT, cm	10.01	WET WEIGHT, gm	396.6
SAMPLE DIAMETER, cm	5.06	DRY WEIGHT, gm	324.9
SAMPLE AREA, cm ²	20.11	WATER CONTENT, %	22.1
SAMPLE VOLUME, cc	201.29	POROSITY, %	
UNIT WEIGHT, kN/m ³	19.31	DRY UNIT WT., kN/m ³	15.82

TEST RESULTS		LIQUID LIMIT, %
COMPRESS. STRESS, kPa	47.7	PLASTIC INDEX, %
STRAIN AT FAILURE, %	20.0	LAB. VANE, Peak, kPa
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.0	29.0	0.25	5.86
50.0	33.0	0.50	6.89
75.0	38.0	0.75	7.91
100.0	43.0	1.00	8.97
150.0	52.0	1.50	10.74
200.0	60.0	2.00	12.33
250.0	68.0	2.50	13.90
300.0	76.0	3.00	15.46
350.0	84.0	3.50	17.00
400.0	91.0	4.00	18.52
450.0	99.0	4.49	19.63
500.0	106.0	4.99	21.12
600.0	122.0	5.99	24.05
700.0	138.0	6.99	26.92
800.0	151.0	7.99	29.13
900.0	164.0	8.99	31.30
1000.0	177.0	9.99	33.41
1100.0	189.0	10.99	35.28
1200.0	200.0	11.99	36.91
1300.0	214.0	12.99	38.08
1400.0	225.0	13.99	40.58
1500.0	235.0	14.99	41.90
1600.0	246.0	15.98	43.34
1700.0	255.0	16.98	44.39
1800.0	264.0	17.98	45.41
1900.0	274.0	18.98	46.55
2000.0	284.0	19.98	47.66

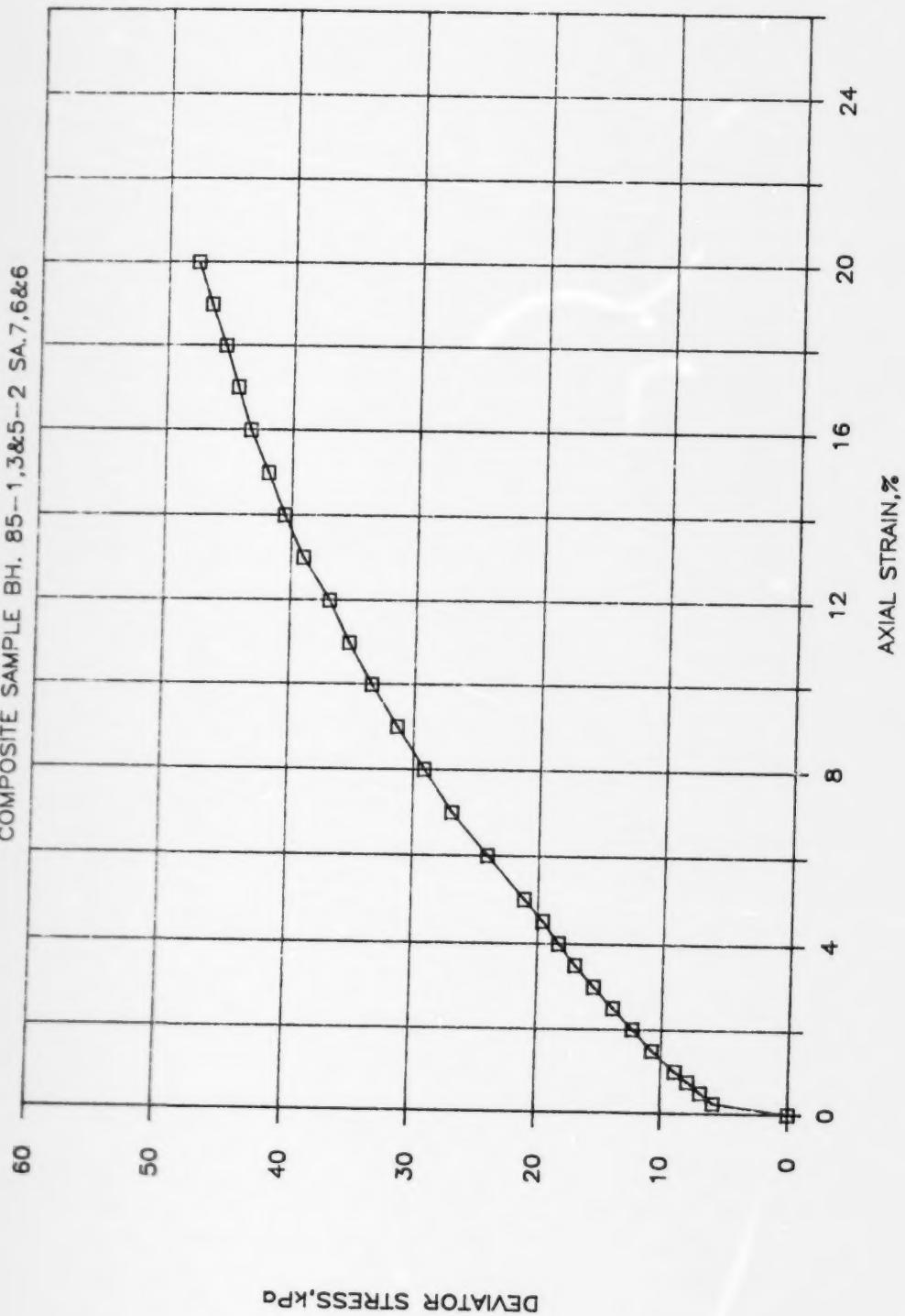
PROJECT 851-1298

(GLAL PROJECT # 85-GT-4)

Golder Associates

PROCTOR COMPOSITE SAMPLE - A

COMPOSITE SAMPLE BH. 85--1,3&5--2 SA.7,6&6



UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 28-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	1 3 5	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	7 6 6	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	UPPER TILL	PROCTOR COMPOSITE SAMPLE - B	

SAMPLE HEIGHT, cm	8.50	WET WEIGHT, gm	367.4
SAMPLE DIAMETER, cm	5.28	DRY WEIGHT, gm	293.6
SAMPLE AREA, cm ²	21.90	WATER CONTENT, %	24.9
SAMPLE VOLUME, cc	186.11	POROSITY, %	
UNIT WEIGHT, kN/m ³	19.35	DRY UNIT WT., kN/m ³	15.49

TEST RESULTS		LIQUID LIMIT, %
COMPRESS. STRESS, kPa	19.7	PLASTIC INDEX, %
STRAIN AT FAILURE, %	20.0	LAB. VANE, Peak, kPa
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa

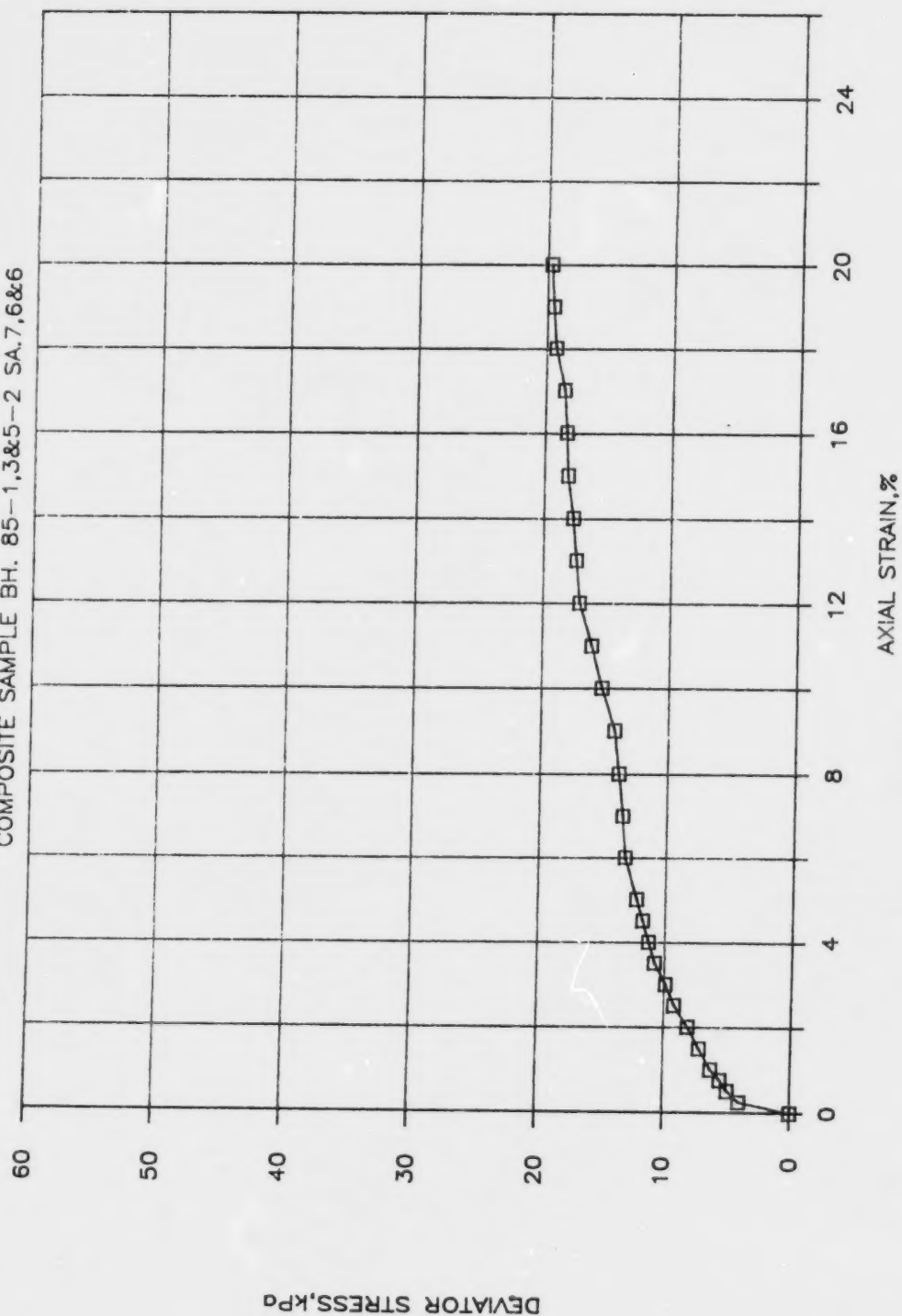
Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
21.3	21.0	0.25	4.03
42.6	26.0	0.50	4.98
63.9	29.0	0.75	5.54
85.2	33.0	1.00	6.29
107.6	38.0	1.50	7.21
129.2	43.0	2.00	8.12
151.8	49.0	2.50	9.20
174.4	53.0	3.00	9.90
197.0	58.0	3.51	10.78
219.6	61.0	4.01	11.28
242.2	64.0	4.51	11.77
264.8	67.0	5.01	12.26
287.4	73.0	6.01	13.21
310.0	75.0	7.01	13.43
332.6	78.0	8.01	13.82
355.2	81.0	9.01	14.19
377.8	88.0	10.01	15.25
400.4	94.0	11.01	16.11
423.0	101.0	12.01	17.12
445.6	104.0	13.01	17.40
468.2	107.0	14.01	17.72
490.8	111.0	15.01	18.17
513.4	113.0	16.01	18.28
536.0	116.0	17.01	18.54
558.6	122.0	18.01	19.26
581.2	125.0	19.01	19.50
603.8	128.0	20.01	19.72

PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

Golder Associates

PROCTOR COMPOSITE SAMPLE - B

COMPOSITE SAMPLE BH. 85-1,3&5-2 SA.7,6&6



UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 29-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

PROJECT NUMBER	851-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	3	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	10 11	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	LOWER TILL	PROCTOR COMPOSITE SAMPLE - A	
SAMPLE HEIGHT, cm	10.07	WET WEIGHT, gm	412.7
SAMPLE DIAMETER, cm	4.97	DRY WEIGHT, gm	347.6
SAMPLE AREA, cm ²	19.40	WATER CONTENT, %	19.7
SAMPLE VOLUME, cc	195.36	POROSITY, %	
UNIT WEIGHT, kN/m ³	20.71	DRY UNIT WT., kN/m ³	17.45
TEST RESULTS		LIQUID LIMIT, %	
COMPRESS. STRESS, kPa	73.7	PLASTIC INDEX, %	
STRAIN AT FAILURE, %	20.0	LAB. VANE, Peak, kPa	
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid. kPa	

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
25.2	36.0	0.25	7.81
50.4	45.0	0.50	9.73
75.6	54.0	0.75	11.65
100.7	61.0	1.00	13.13
151.1	73.0	1.50	15.63
201.5	85.0	2.00	18.11
251.9	96.0	2.50	20.35
302.3	108.0	3.00	22.77
352.7	119.0	3.50	24.96
403.1	130.0	4.00	27.13
453.5	141.0	4.50	29.27
503.9	152.0	5.00	31.39
604.6	173.0	6.00	35.35
705.3	196.0	7.00	39.62
806.0	215.0	8.00	42.99
906.7	235.0	9.00	46.48
1007.4	255.0	10.00	49.88
1108.1	274.0	11.00	53.01
1208.8	295.0	12.00	56.43
1309.5	314.0	13.00	59.30
1410.2	331.0	14.00	61.87
1510.9	347.0	15.00	64.11
1611.6	363.0	16.00	66.28
1712.3	378.0	17.00	68.19
1813.0	396.0	18.00	70.58
1913.7	409.0	19.00	72.01
2014.4	424.0	20.00	73.73

PROJECT 851-1298

(GLAL PROJECT # 85-6T-4)

Golder Associates

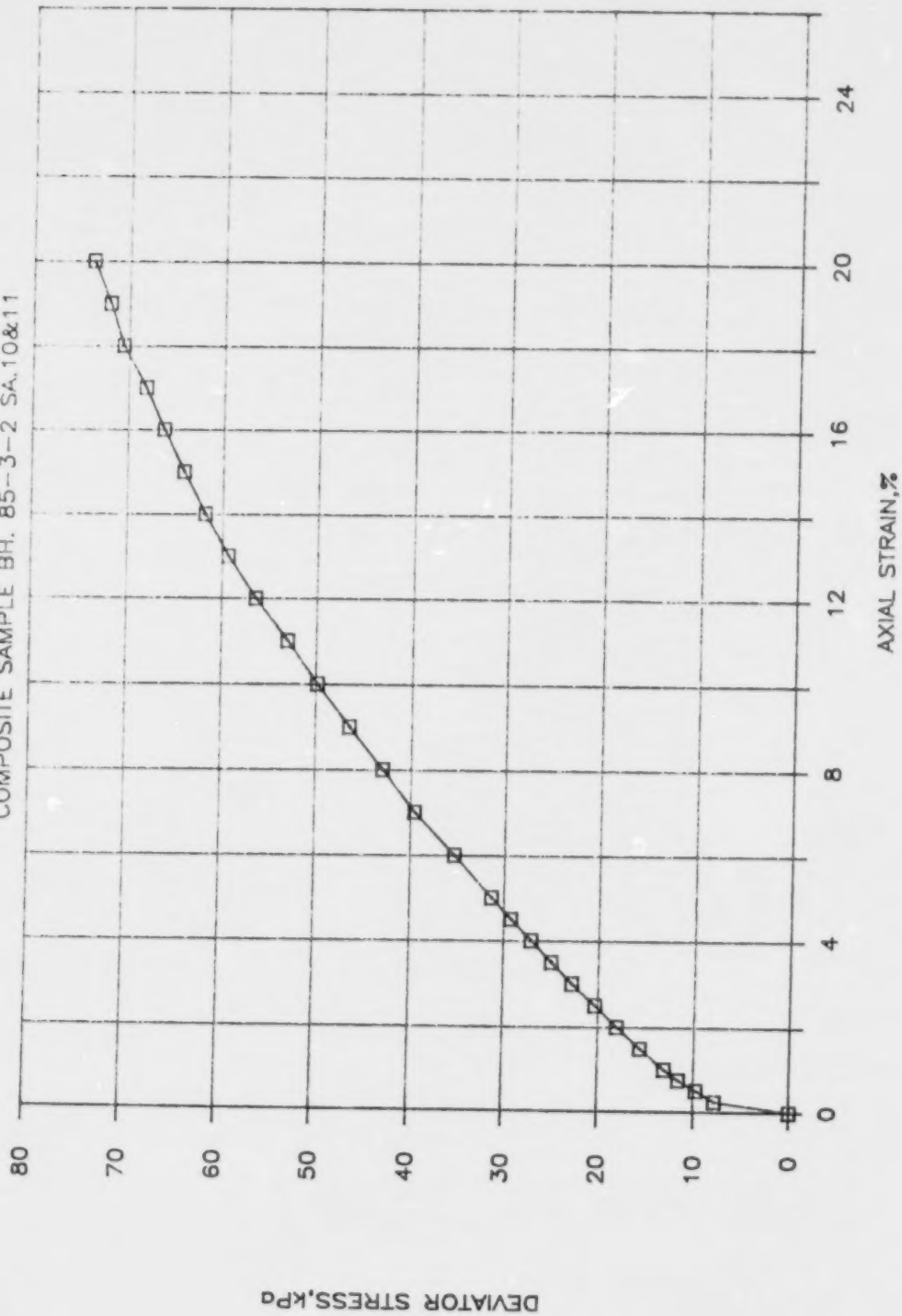
UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 29-2

PROCTOR COMPOSITE SAMPLE - A

COMPOSITE SAMPLE BH. 85-3-2 SA.10&11



Golder Associates

UNDRAINED TRIAXIAL COMPRESSION (U)

FIGURE 30-1

SHEET 1 OF 2

UNDRAINED TRIAXIAL COMPRESSION TEST (U)

=====

PROJECT NUMBER	951-1298	PROVING RING, kg/mm div.	0.043
BOREHOLE NUMBER	3	STRAIN RATE mm/min	0.2032
SAMPLE NUMBER	10 11	SPECIFIC GRAVITY, assumed	2.78
SAMPLE DEPTH, m	LOWER TILL	PROCTOR COMPOSITE SAMPLE - B	

=====

SAMPLE HEIGHT, cm	9.95	WET WEIGHT, gm	411.4
SAMPLE DIAMETER, cm	4.94	DRY WEIGHT, gm	340.3
SAMPLE AREA, cm ²	19.17	WATER CONTENT, %	20.8
SAMPLE VOLUME, cc	190.71	POROSITY, %	
UNIT WEIGHT, kN/m ³	21.15	DRY UNIT WT., kN/m ³	17.51

=====

TEST RESULTS		LIQUID LIMIT, %
COMPRESS. STRESS, kPa	33.3	PLASTIC INDEX, %
STRAIN AT FAILURE, %	20.0	LAB. VANE, Peak, kPa
CELL PRESSURE, kPa	0.0	LAB. VANE, Resid, kPa

=====

Strain Dial mm	Load Dial mm	Axial Strain %	Deviator Stress kPa
0.0	0.0	0	0.00
24.8	23.0	0.25	5.05
49.7	27.0	0.50	5.91
74.5	30.0	0.75	6.55
99.5	33.0	1.00	7.19
149.2	39.0	1.50	8.45
198.9	43.5	2.00	9.38
248.6	49.0	2.50	10.51
298.3	55.0	3.00	11.74
348.0	60.0	3.50	12.74
397.7	67.0	4.00	14.15
447.4	74.0	4.50	15.55
497.1	79.0	5.00	16.51
596.6	89.0	6.00	18.41
696.1	99.0	7.00	20.26
795.6	106.5	8.00	21.56
895.1	113.0	9.00	22.62
994.6	122.0	10.00	24.16
1094.1	130.0	11.00	25.46
1193.6	139.0	12.00	26.91
1293.1	147.0	13.00	28.14
1392.6	151.0	14.00	28.97
1492.1	158.0	15.00	29.55
1591.6	163.0	16.00	30.13
1691.1	169.0	17.00	30.86
1790.6	176.0	18.00	31.75
1890.1	184.0	19.00	32.79
1989.6	199.0	20.00	33.27

PROJECT 851-1298

(GLAL PROJECT # 85-GT-4)

Golder Associates

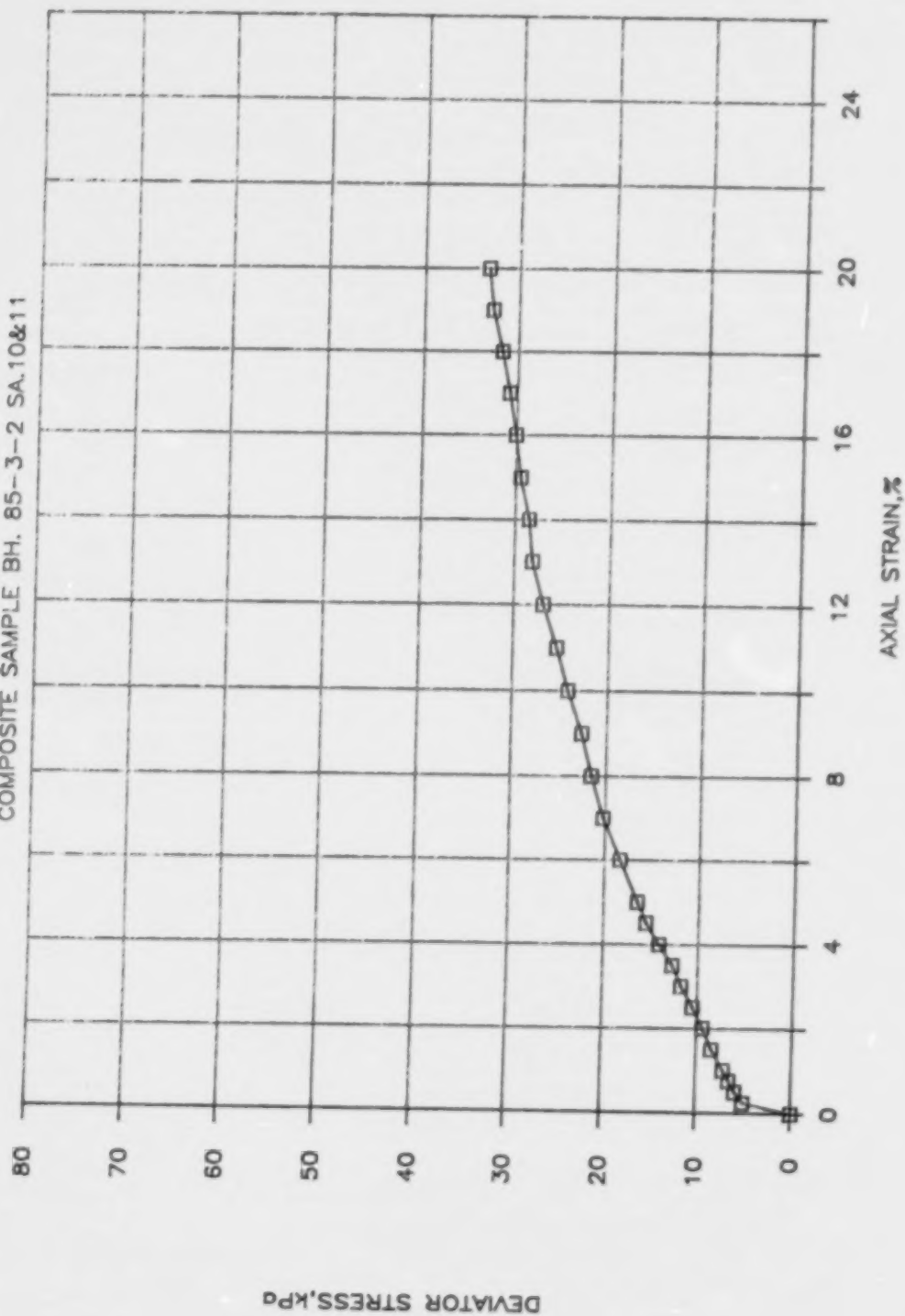
UNDRAINED TRIAXIAL COMPRESSION (U)

SHEET 2 OF 2

FIGURE 30-2

PROCTOR COMPOSITE SAMPLE - B

COMPOSITE SAMPLE BH. 85-3-2 SA.10&11



May, 1986

851-1298

CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS

FIGURES 31-1 to 33-3

CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
SHEET 1 OF 3

FIGURE 31-1

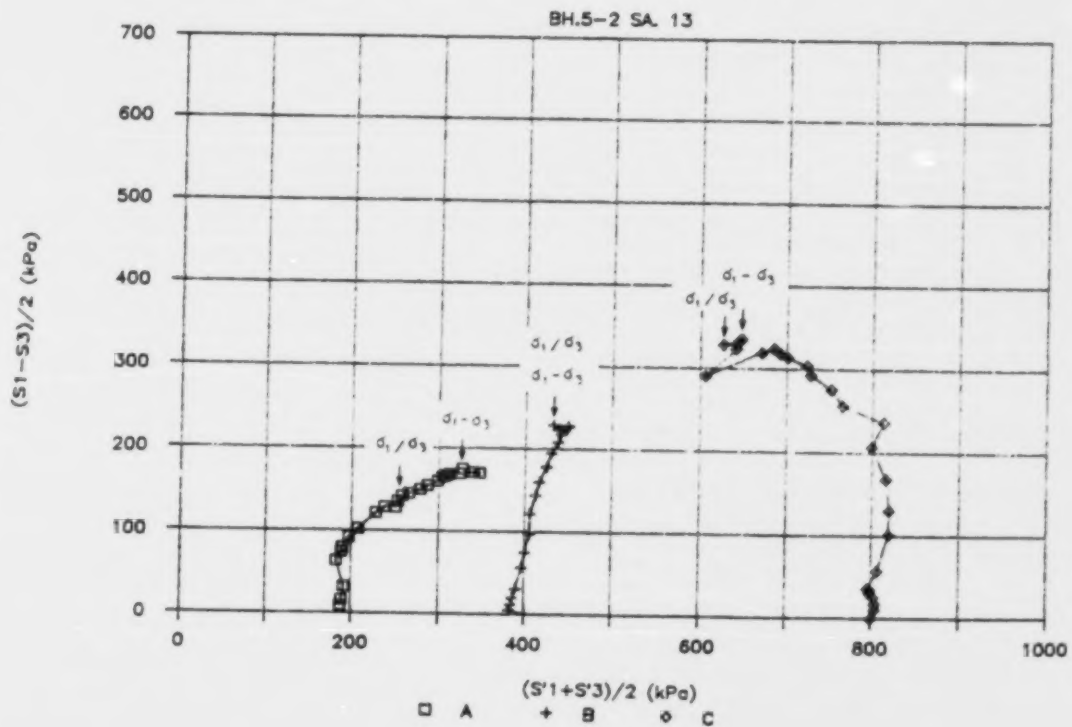
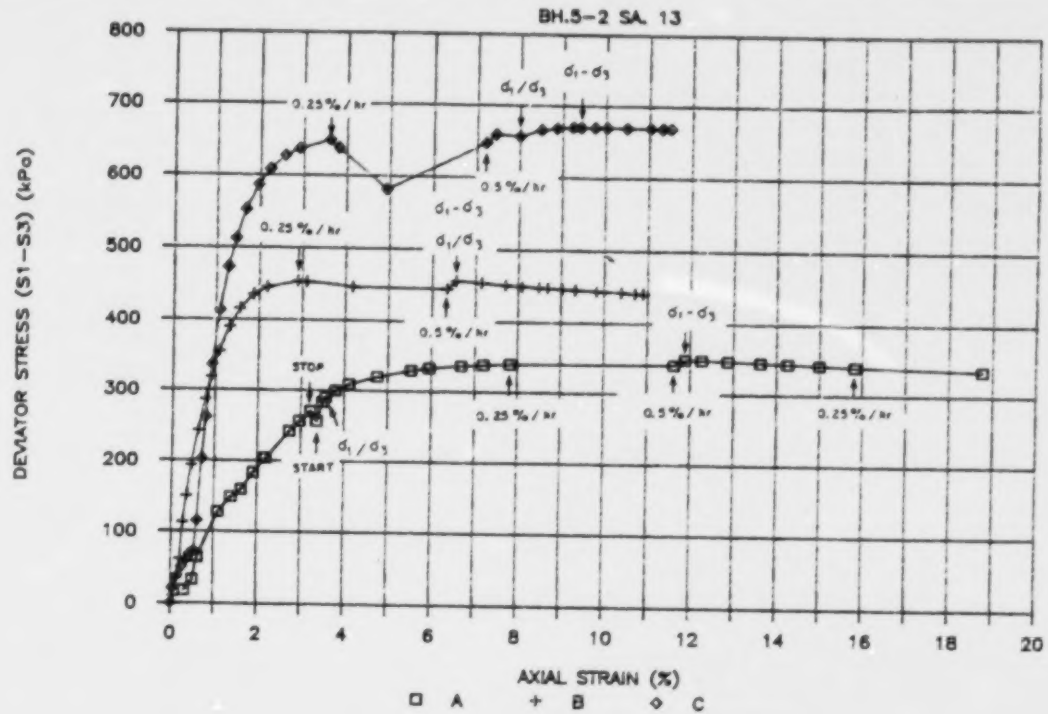
CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS

	A	B	C
BOREHOLE NUMBER	85-5-2	85-5-2	85-5-2
SAMPLE NUMBER	13	13	13
SAMPLE DEPTH, m	9.94	10.07	10.19
SPECIMEN DIAMETER, cm	5.03	5.10	5.04
SPECIMEN HEIGHT, cm	10.12	10.15	10.16
WATER CONTENT BEFORE CONSOLIDATION %	20	20	21
CELL PRESSURE, kPa	330.7	600.1	930.8
BACK PRESSURE, kPa	130.9	199.8	130.9
PORE PRESSURE PARAMETER, B	0.97	0.98	0.97
CONSOLIDATION PRESSURE, σ_c , kPa	199.8	400.3	799.9
VOLUME CHANGE CONSOLIDATION, V_c , cc	-6.0	-7.0	-10.3
WATER CONTENT AFTER CONSOLIDATION %	18	18	18
AVERAGE RATE OF STRAIN, %/hr	0.50	0.50	0.50
AVERAGE LOAD INCREMENT, kPa			
AVERAGE LOAD DURATION, hr			
TIME TO FAILURE, days	2	2	2
WATER CONTENT AFTER TEST %	18	18	18
MAX. DEVIATOR STRESS, $(\sigma_1 - \sigma_3)$, kPa	349.7	456.5	670.7
AXIAL STRAIN AT FAILURE, $(\epsilon_1 - \epsilon_3)_{max}$, %	11.9	6.5	9.2
MAX EFFECTIVE PRINCIPAL STRESS			
RATIO, $(\sigma_1' / \sigma_3')_{max}$, %	3.4	3.2	3.2
AXIAL STRAIN AT $(\sigma_1' / \sigma_3')_{max}$, %	3.5	6.5	8.0
PORE PRESSURE PARAMETER, A_f	0.136	0.430	0.727
NATURAL WATER CONTENT, w, %	19	19	20
LIQUID LIMIT, w_l	30		
PLASTIC LIMIT, w_p	19		
DRY UNIT WEIGHT, γ_d , kN/m ³	18.06	17.79	17.35
FILTER DRAINS USED, y/n	Y	y	y
SAMPLE DESCRIPTION	A, brown fissured clay silt to silty clay some fine gravel B, brown fissured clayey silt to silty clay some fine gravel C, brown silty clay to clayey silt with some fine gravel		
RATE OF STRAIN, %/hr, CHANGED	n/a	n/a	n/a
AXIAL STRAIN, %, WHERE CHANGED	n/a	n/a	n/a
FAILURE PLANE NUMBER	n/a	n/a	n/a
ANGLE OF FAILURE, DEGREES	bulging	bulging	bulging
LAB. VANE PEAK STRENGTH (kPa)			
LAB. VANE RESIDUAL STRENGTH (kPa)			
DATE	March, 1986		
PROJECT NUMBER	851-1298 (GLAL PROJECT # 85-GT-4)		
DATA BY	F.A.R.		

CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS

SHEET 2 OF 3

FIGURE 31-2

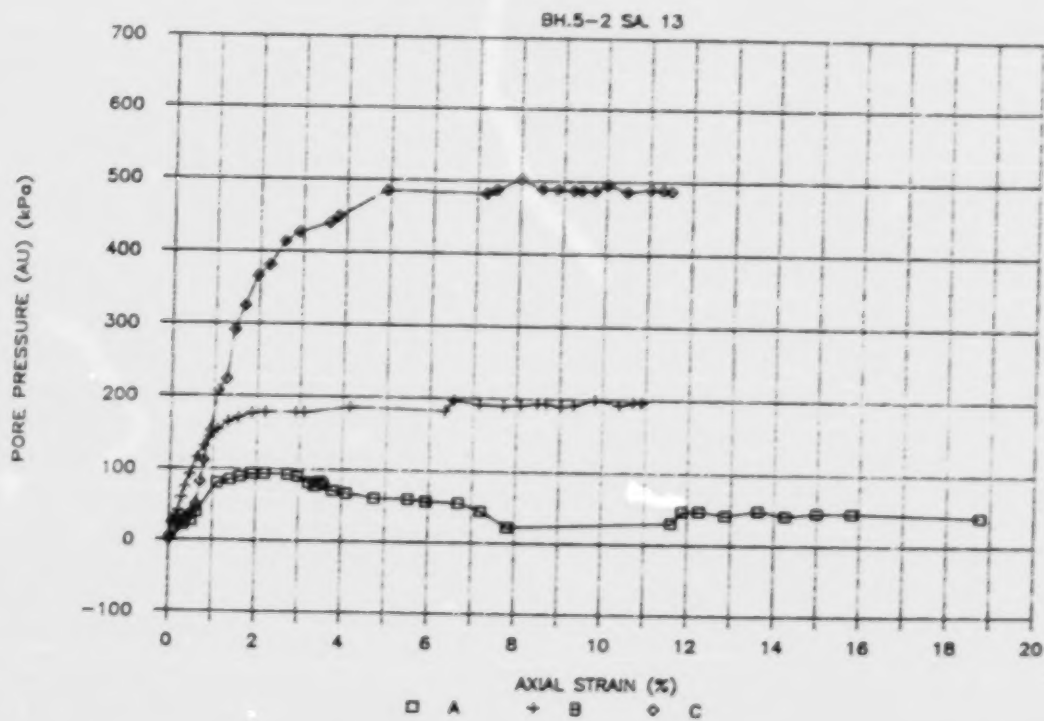
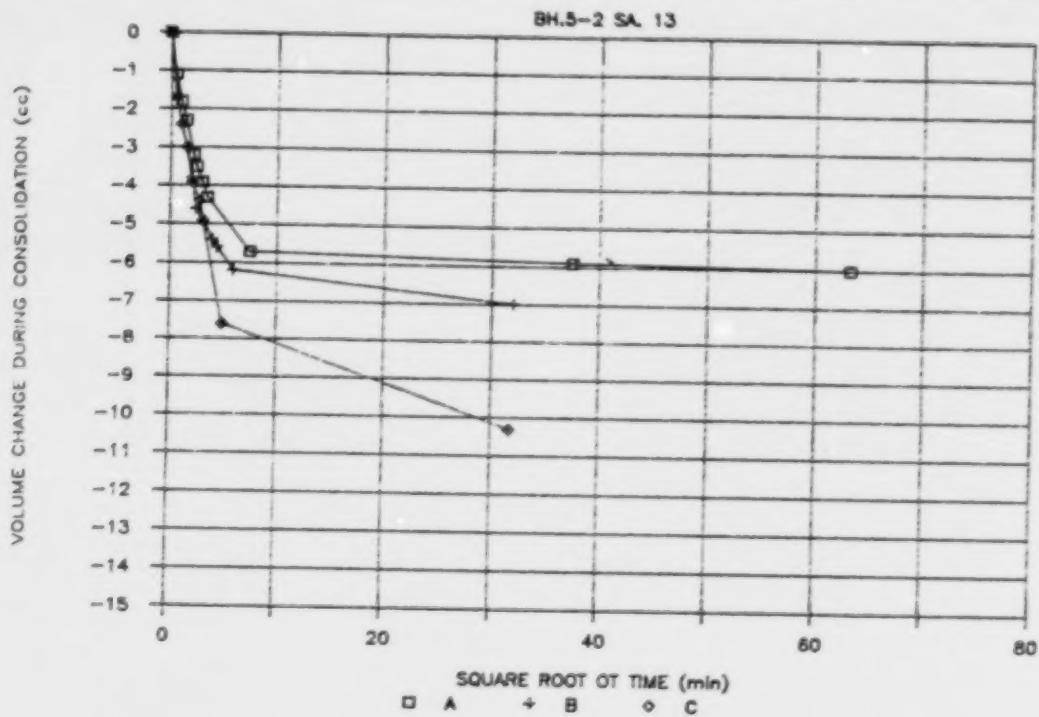


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CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS

SHEET 3 OF 3

FIGURE 31-3



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CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
SHEET 1 OF 3

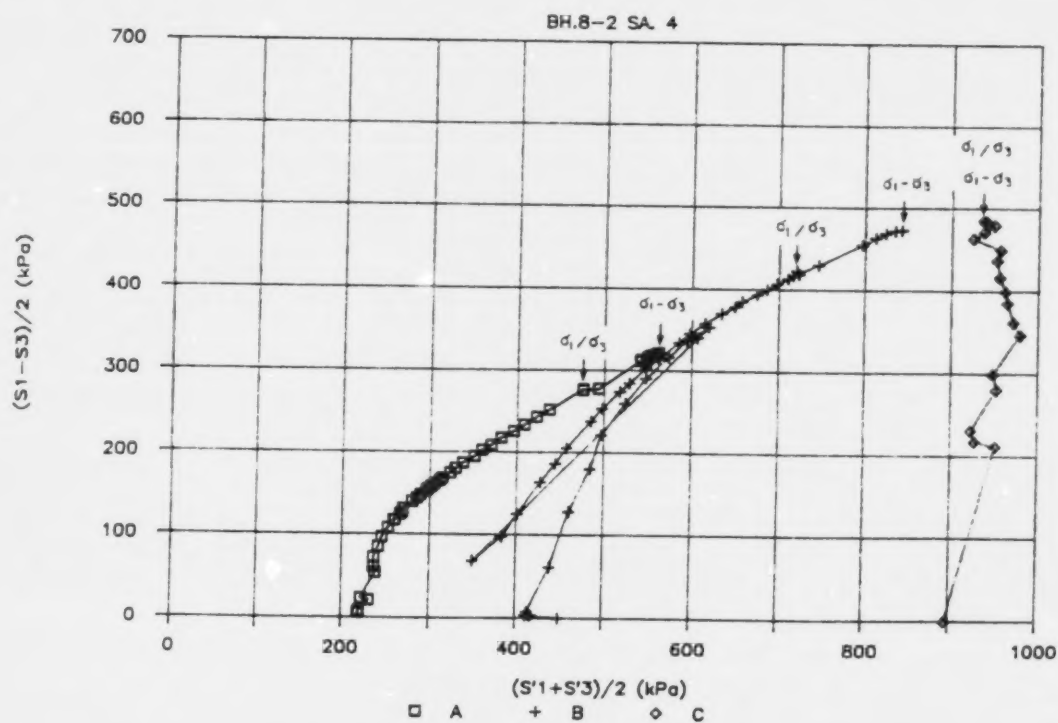
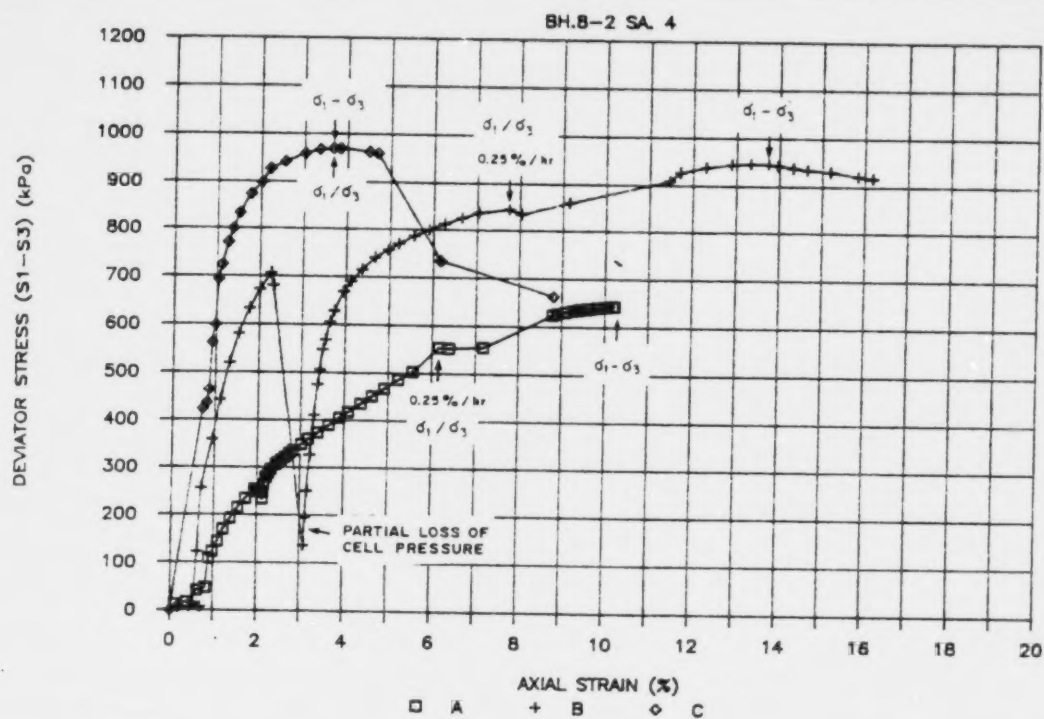
FIGURE 32-1

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS			
	A	B	C
BOREHOLE NUMBER	85-8-2	85-8-2	85-8-2
SAMPLE NUMBER	4	4	4
SAMPLE DEPTH , m	2.82	2.95	2.79
SPECIMEN DIAMETER , cm	5.01	5.05	5.00
SPECIMEN HEIGHT , cm	10.14	10.09	10.12
WATER CONTENT BEFORE CONSOLIDATION %	19	21	22
CELL PRESSURE , kPa	287.3	580.8	1026.6
BACK PRESSURE, kPa	62.0	130.9	130.9
PORE PRESSURE PARAMETER ,B	0.97	0.98	0.98
CONSOLIDATION PRESSURE,Sc, kPa	225.3	449.9	895.7
VOLUME CHANGE CONSOLIDATION,Vc,cc	-7.2	-4.4	-11.3
WATER CONTENT AFTER CONSOLIDATION %	17	20	19
AVERAGE RATE OF STRAIN,%/hr	0.50	0.50	0.50
AVERAGE LOAD INCREMENT, kPa			
AVERAGE LOAD DURATION ,hr			
TIME TO FAILURE ,days	2	2	1
WATER CONTENT AFTER TEST %	19	20	20
MAX.DEVIATOR STRESS,(S1-S3),kPa	643.6	946.8	971.1
AXIAL STRAIN AT FAILURE,(S1-S3)max.%	10.2	13.3	3.7
MAX EFFECTIVE PRINCIPAL STRESS			
RATIO ,(S1/S3)max.%	3.8	3.8	2.5
AXIAL STRAIN AT (S1/S3)max.	6.2	7.7	3.7
PORE PRESSURE PARAMETER,Af	-0.023	0.006	0.459
NATURAL WATER CONTENT ,w, %	19	20	21
LIQUID LIMIT, wL	35		
PLASTIC LIMIT, wP	17		
DRY UNIT WEIGHT, γ_n/m^3	17.68	17.12	16.95
FILTER DRAINS USED ,y/n	Y	Y	Y
SAMPLE DESCRIPTION	A.stiff brown silty clay to clayey silt. some gypsum pockets B.same as sample A C.same as sample A		
RATE OF STRAIN,%/hr.CHANGED	n/a	n/a	n/a
AXIAL STRAIN,%,WHERE CHANGED	n/a	n/a	n/a
FAILURE PLANE NUMBER	n/a	n/a	n/a
ANGLE OF FAILURE, DEGREES	bulging	64	65
LAB. VANE PEAK STRENGTH (kPa)			
LAB.VANE RESIDUAL STRENGTH (kPa)			
DATE	March,1986		
PROJECT NUMBER	851-1298 (GLAL PROJECT # 85-GT-4)		
DATA BY	F.A.R.		

CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS

SHEET 2 OF 3

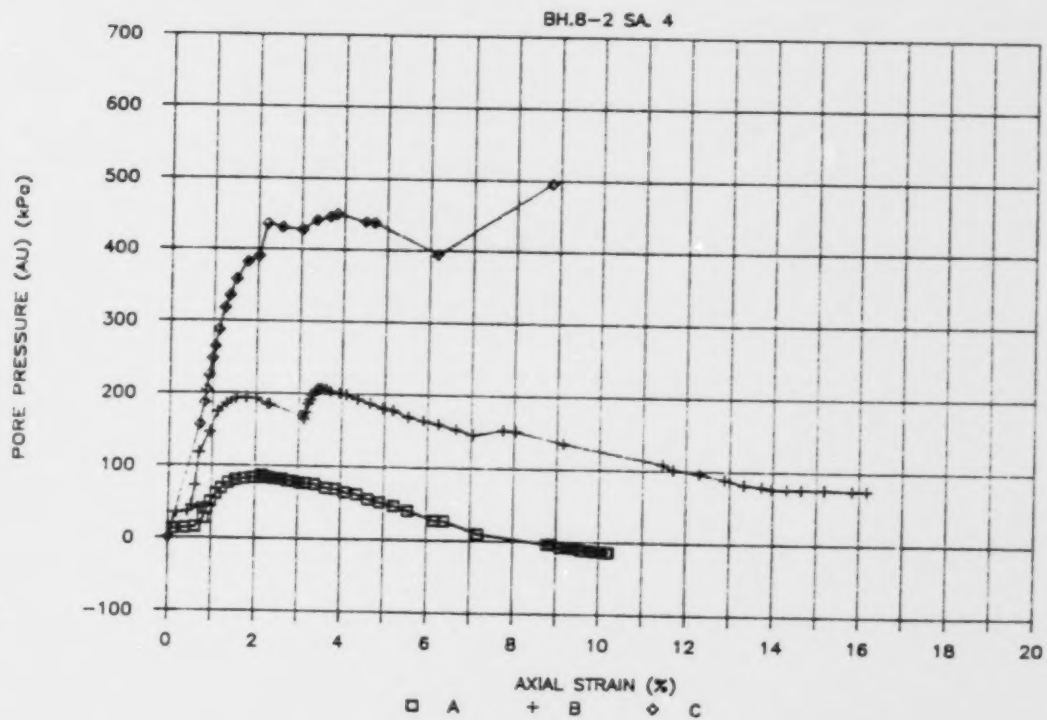
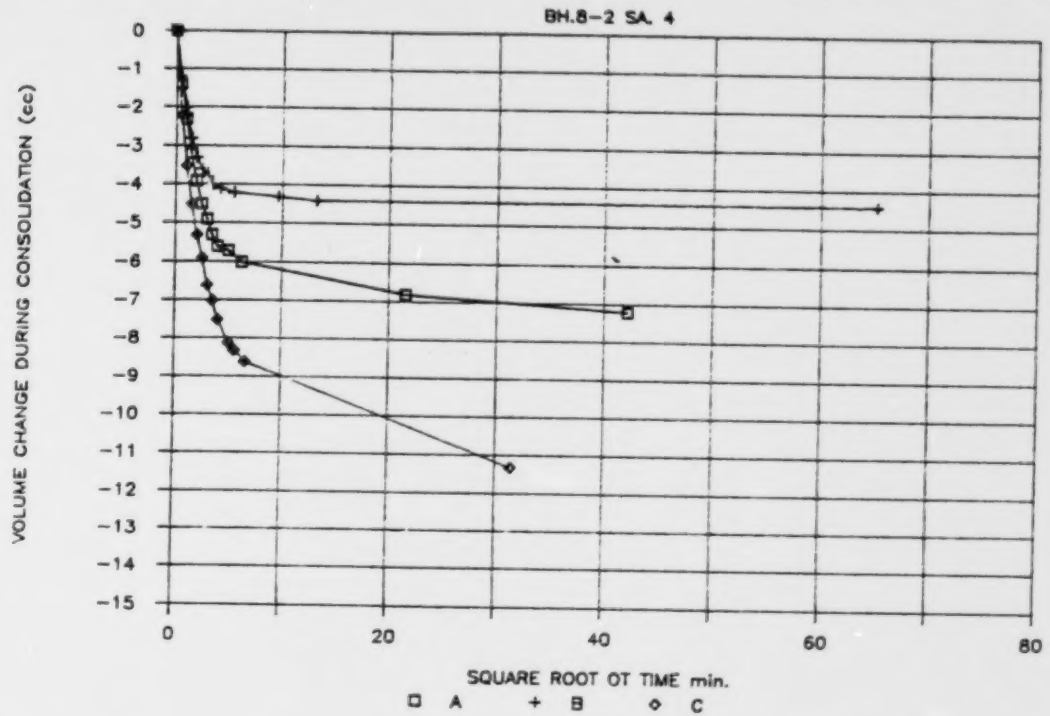
FIGURE 32-2



CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS

SHEET 3 OF 3

FIGURE 32-3



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CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
SHEET 1 OF 3

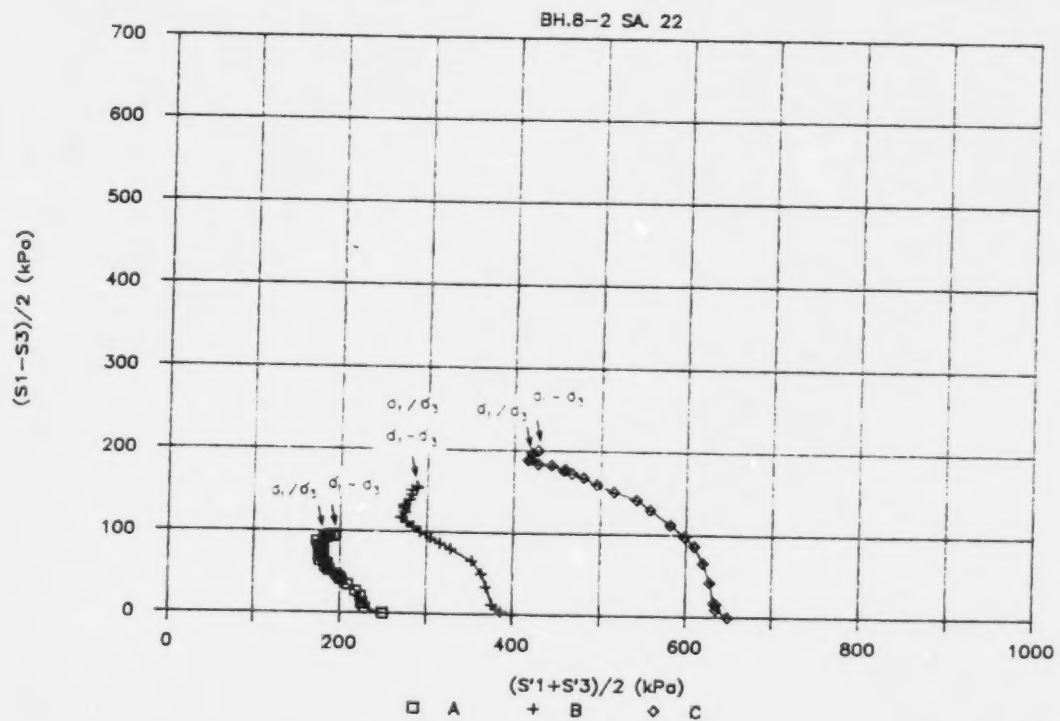
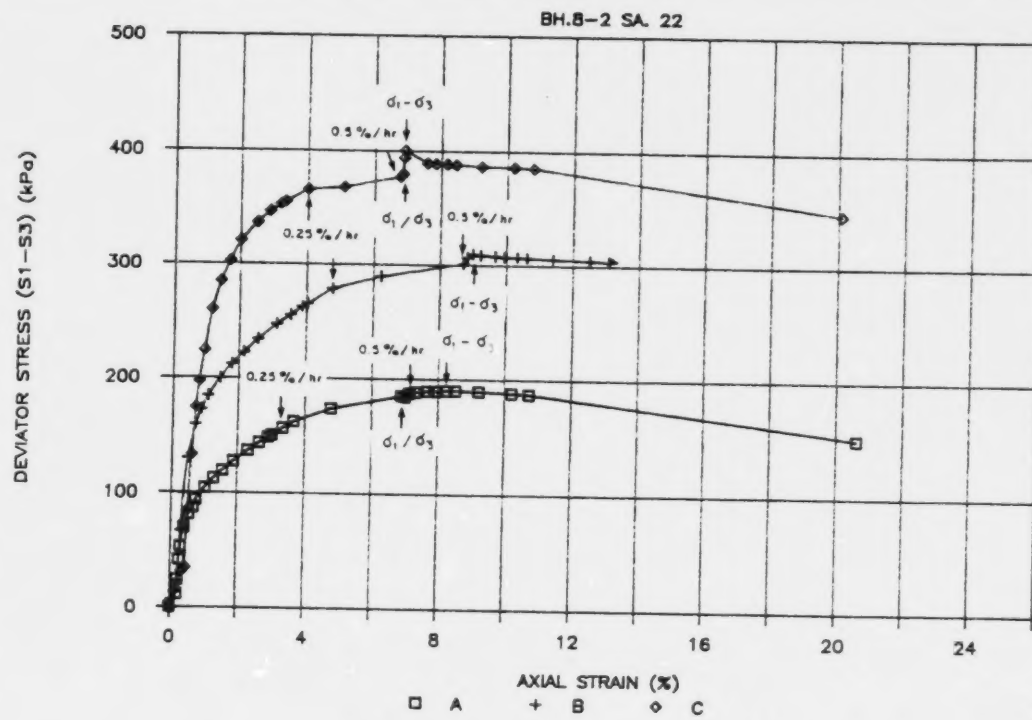
FIGURE 33-1

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS			
	A	B	C
BOREHOLE NUMBER	85-8-2	85-8-2	85-8-2
SAMPLE NUMBER	22	22	22
SAMPLE DEPTH, m	27.77	27.90	24.00
SPECIMEN DIAMETER, cm	4.99	5.00	5.04
SPECIMEN HEIGHT, cm	10.17	10.19	10.12
WATER CONTENT BEFORE CONSOLIDATION %	35	27	30
CELL PRESSURE, kPa	381.0	599.4	711.7
BACK PRESSURE, kPa	130.9	199.8	62.0
PORE PRESSURE PARAMETER, B	0.97	0.96	0.98
CONSOLIDATION PRESSURE, Sc, kPa	250.1	399.6	649.7
VOLUME CHANGE CONSOLIDATION, Vc, cc	-14.7	-14.9	-21.0
WATER CONTENT AFTER CONSOLIDATION %	30	22	23
AVERAGE RATE OF STRAIN, %/hr	0.50	0.50	0.50
AVERAGE LOAD INCREMENT, kPa			
AVERAGE LOAD DURATION, hr			
TIME TO FAILURE, days	2	2	2
WATER CONTENT AFTER TEST %	30	22	24
MAX. DEVIATOR STRESS, (S1-S3), kPa	190.3	309.6	400.9
AXIAL STRAIN AT FAILURE, (S1-S3)max, %	8.2	9.0	6.9
MAX EFFECTIVE PRINCIPAL STRESS			
RATIO, (S1/S3)max, %	3.1	3.3	2.8
AXIAL STRAIN AT (S1/S3)max, %	6.9	9.0	6.9
PORE PRESSURE PARAMETER, Af	0.829	0.863	1.057
NATURAL WATER CONTENT, w, %	33	22	28
LIQUID LIMIT, wL		32	
PLASTIC LIMIT, wP		15	
DRY UNIT WEIGHT, kN/m ³	14.54	15.92	15.38
FILTER DRAINS USED, y/n	Y	Y	Y
SAMPLE DESCRIPTION	A. irregular layered red grey silty clay to clayey silt B. same as sample A C. same as sample A		
RATE OF STRAIN, %/hr. CHANGED	n/a	n/a	n/a
AXIAL STRAIN, %, WHERE CHANGED	n/a	n/a	n/a
FAILURE PLANE NUMBER	n/a	n/a	n/a
ANGLE OF FAILURE, DEGREES	bulging	bulging	bulging
LAB. VANE PEAK STRENGTH (kPa)			
LAB. VANE RESIDUAL STRENGTH (kPa)			
DATE	March, 1986		
PROJECT NUMBER	851-1298 (GLAL PROJECT # 85-GT-4)		
DATA BY	F.A.R.		

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CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
SHEET 2 OF 3

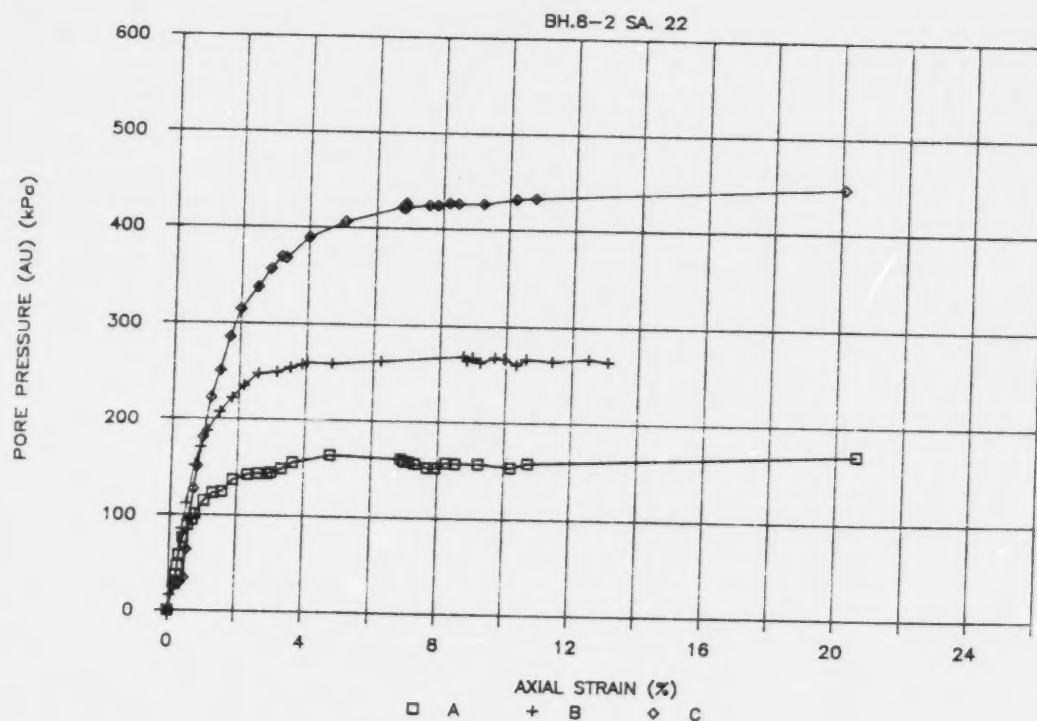
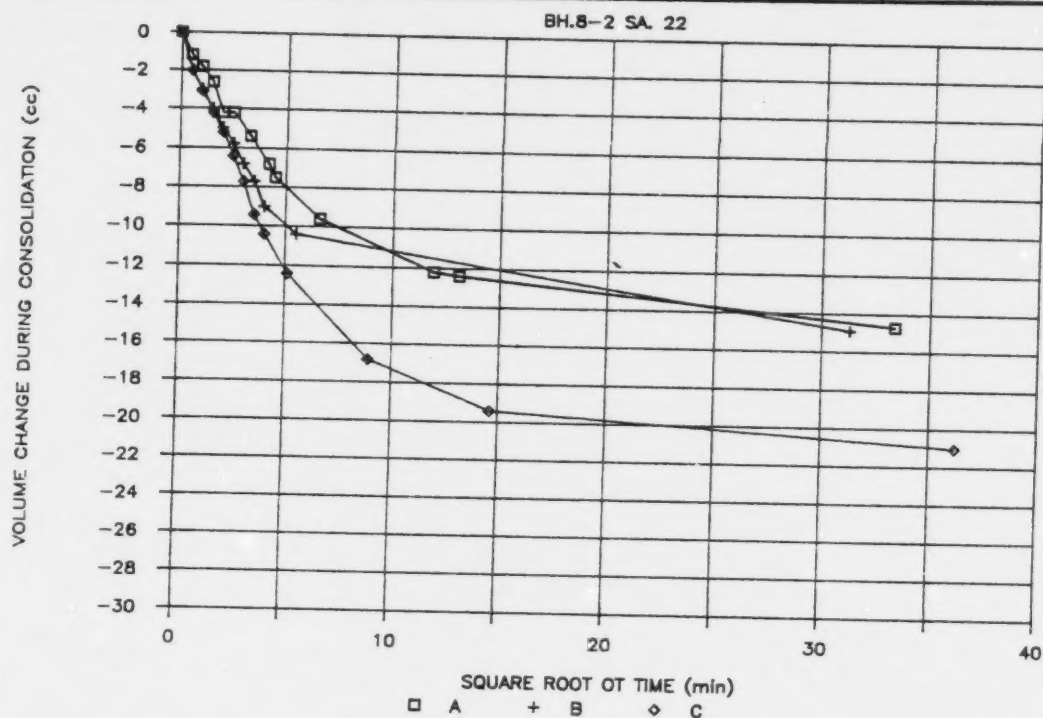
FIGURE 33-2



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CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
SHEET 3 OF 3

FIGURE 33-3



Date _____
Project _____

Golder Associates

Data by _____
Checked by _____

May, 1986

851-1298

CONSOLIDATED DRAINED DIRECT SHEAR TEST

FIGURES 34-1 to 39-3

CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 1 OF 3

FIGURE 34-1

CONSOLIDATED DRAINED DIRECT SHEAR TESTS

TEST NUMBER	A	B	C
BOREHOLE NUMBER	85-3-2	85-3-2	85-3-2
SAMPLE NUMBER	6	6	6
SAMPLE DEPTH, m	4.85	4.92	5.05
SAMPLE HEIGHT, mm	25.20	25.20	25.20
SAMPLE WIDTH, mm	59.50	59.65	59.65
WATER CONTENT, BEFORE CONSOLIDATION, %	32	30	30
NORMAL (CONSOLIDATION) STRESS, kPa	300	599	1000
WATER CONTENT, SHEAR PLANE, %	32	33	31
AVERAGE RATE OF STRAIN, %/hr.	0.5	0.5	0.5
TIME TO FAILURE, days	1.5	1.5	1.5
PEAK SHEAR STRESS, kPa	128.1	194.4	350.6
RESIDUAL SHEAR STRESS, kPa, first pass			
second pass			
third pass			
HORIZONTAL DISPLACEMENT AT PEAK, mm	2.12	2.46	2.94
HORIZONTAL DISPLACEMENT, RESIDUAL, mm			
first pass			
second pass			
third pass			
NATURAL WATER CONTENT, %	32	33	29
LIQUID LIMIT, w _L	61		
PLASTIC LIMIT, w _p	31		
UNIT WEIGHT, kN/m ³	19.15	19.08	19.20
SAMPLE DESCRIPTION	A, red silty clay with some fine gravel		
	B, same as sample A		
	C, same as sample A		

FAILURE PLANE MATERIAL as above description

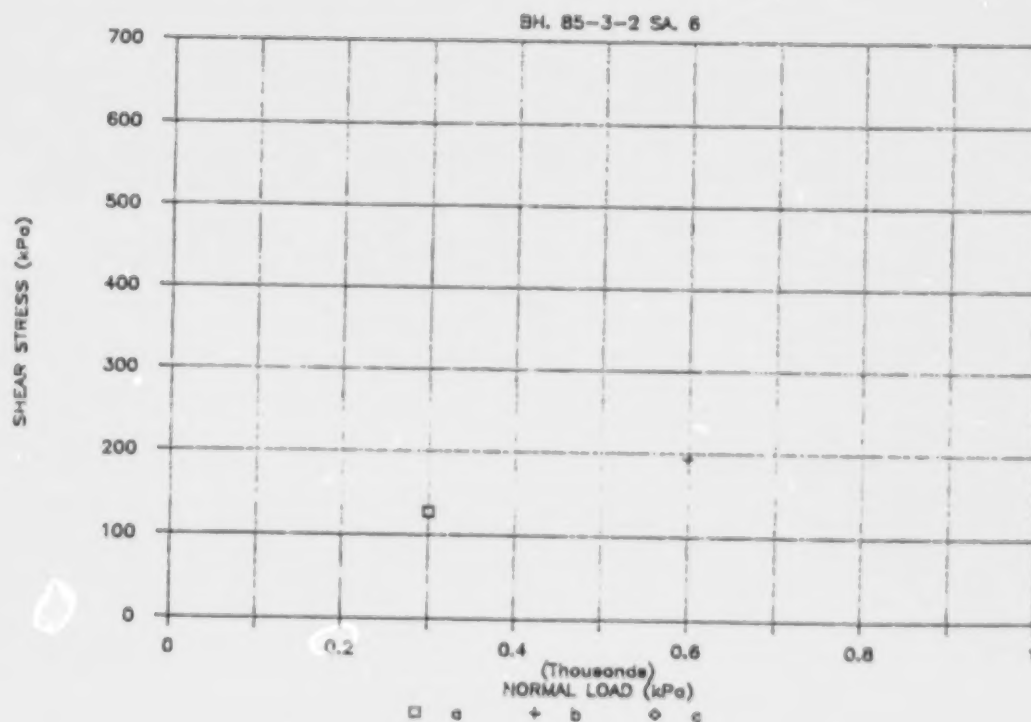
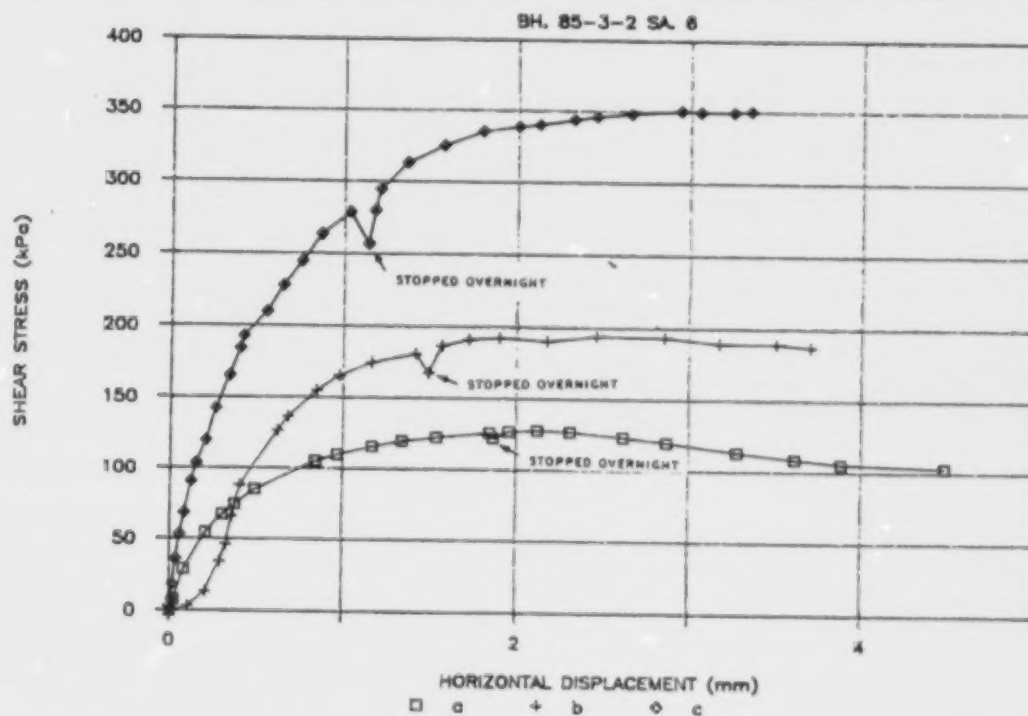
DATE March 1986

PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

DATA BY F.A.R.

CONSOLIDATED DRAINED DIRECT SHEAR TEST
SHEET 2 OF 3

FIGURE 34-2

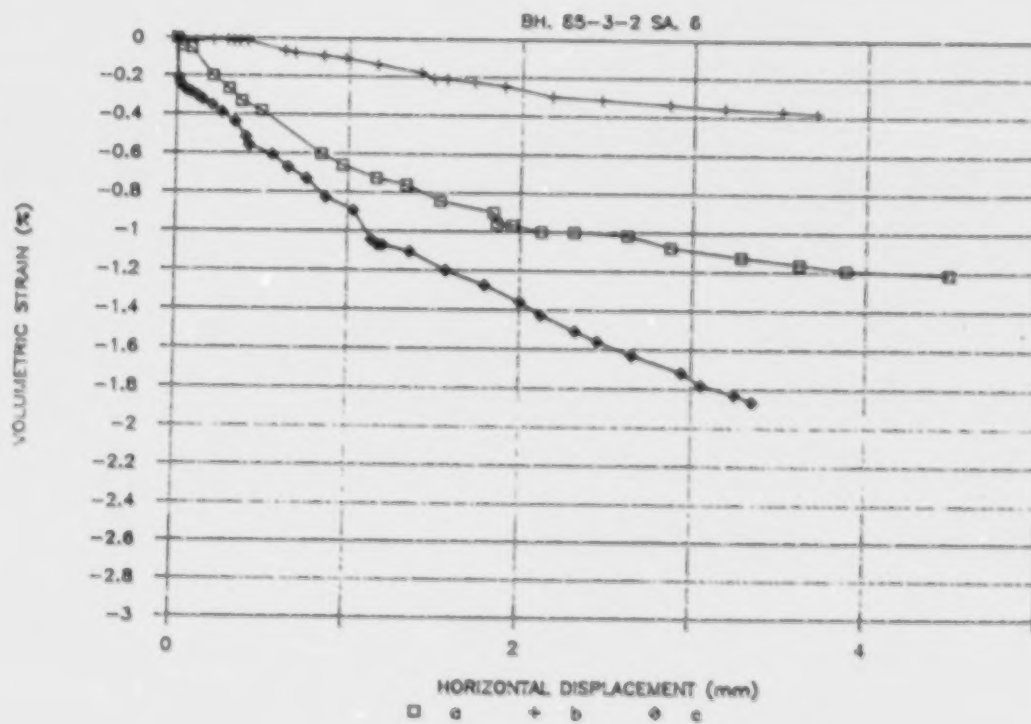
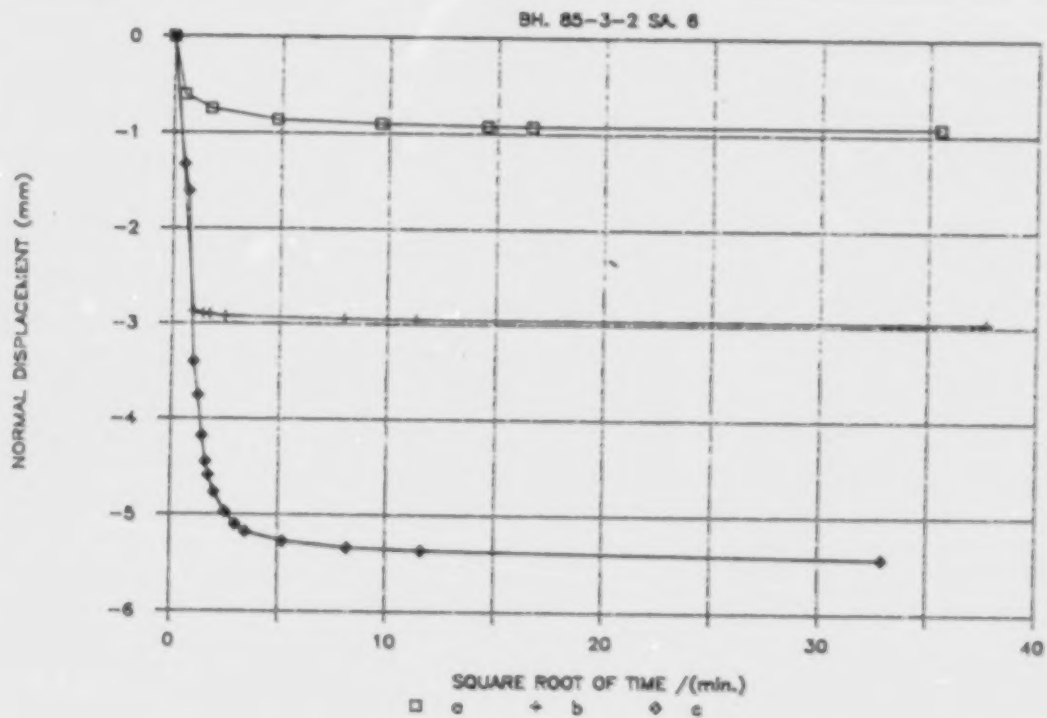


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CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 3 OF 3

FIGURE 34-3



Golder Associates

CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 1 OF 3

FIGURE 35-1

CONSOLIDATED DRAINED DIRECT SHEAR TESTS

TEST NUMBER	A	B	C
BOREHOLE NUMBER	85-3-2	85-3-2	85-3-2
SAMPLE NUMBER	11	11	11
SAMPLE DEPTH, m	12.55	12.60	12.70
SAMPLE HEIGHT, mm	25.00	25.20	25.00
SAMPLE WIDTH, mm	59.50	59.50	59.50
WATER CONTENT, BEFORE CONSOLIDATION, %	21	19	21
NORMAL (CONSOLIDATION) STRESS, kPa	227	498	750
WATER CONTENT, SHEAR PLANE, %	21	18	18
AVERAGE RATE OF STRAIN, %/hr.	0.5	0.5	0.5
TIME TO FAILURE, days	1.5	1.5	1.5
PEAK SHEAR STRESS, kPa	48.9	242.6	315.6
RESIDUAL SHEAR STRESS, kPa, first pass	40.0	136.2	207.3
fifth pass	29.3	148.6	160.4
sixth pass	45.2	207.8	295.2
HORIZONTAL DISPLACEMENT AT PEAK, mm	4.21	7.28	4.23
HORIZONTAL DISPLACEMENT, RESIDUAL, mm			
first pass	9.56	25.74	14.24
fifth pass	58.61	96.08	54.29
sixth pass	70.17	112.36	65.96
NATURAL WATER CONTENT, %	21	19	21
LIQUID LIMIT, w _l			35
PLASTIC LIMIT, w _p			18
UNIT WEIGHT, kN/m ³	20.83	20.85	19.20
SAMPLE DESCRIPTION	A, red silty clay with some fine gravel B, same as sample A C, same as sample A		

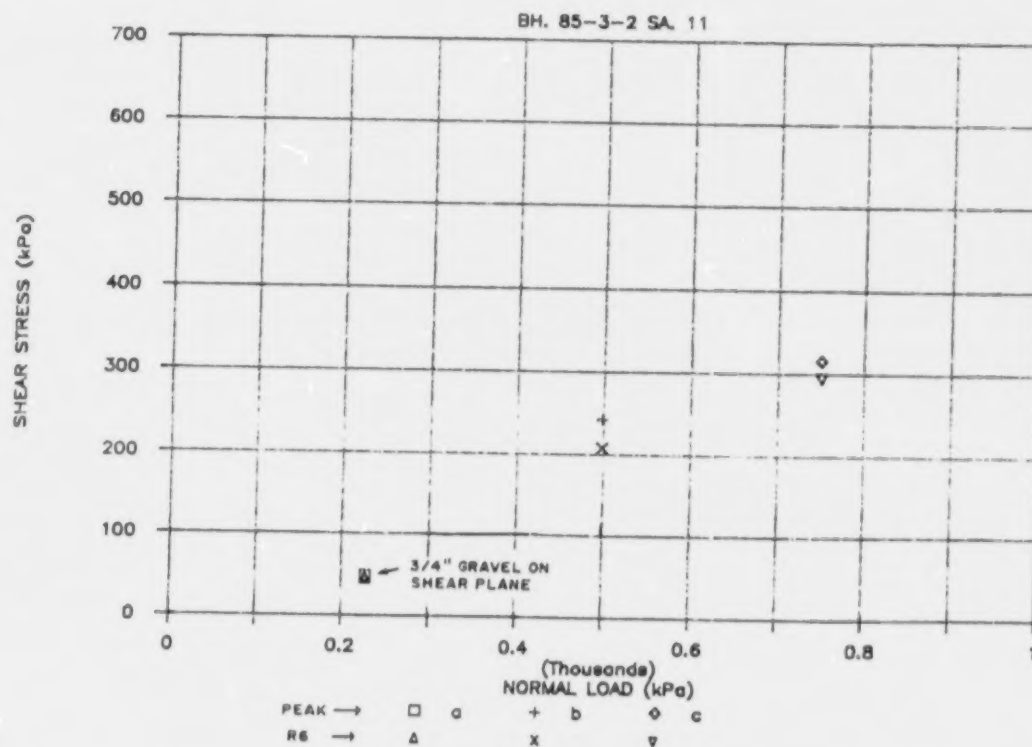
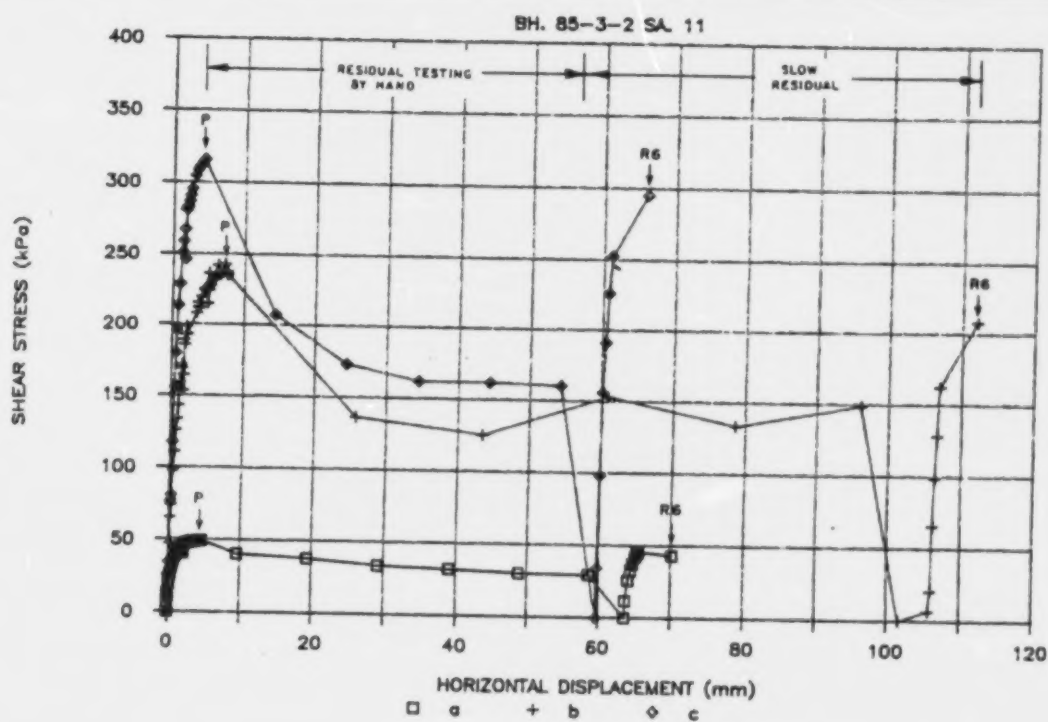
FAILURE PLANE MATERIAL (a) as above, gravel on failure plane

DATE March 1986
PROJECT 851-1298 (SLAL PROJECT # 85-GT-4)
DATA BY F.A.R.

CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 2 OF 3

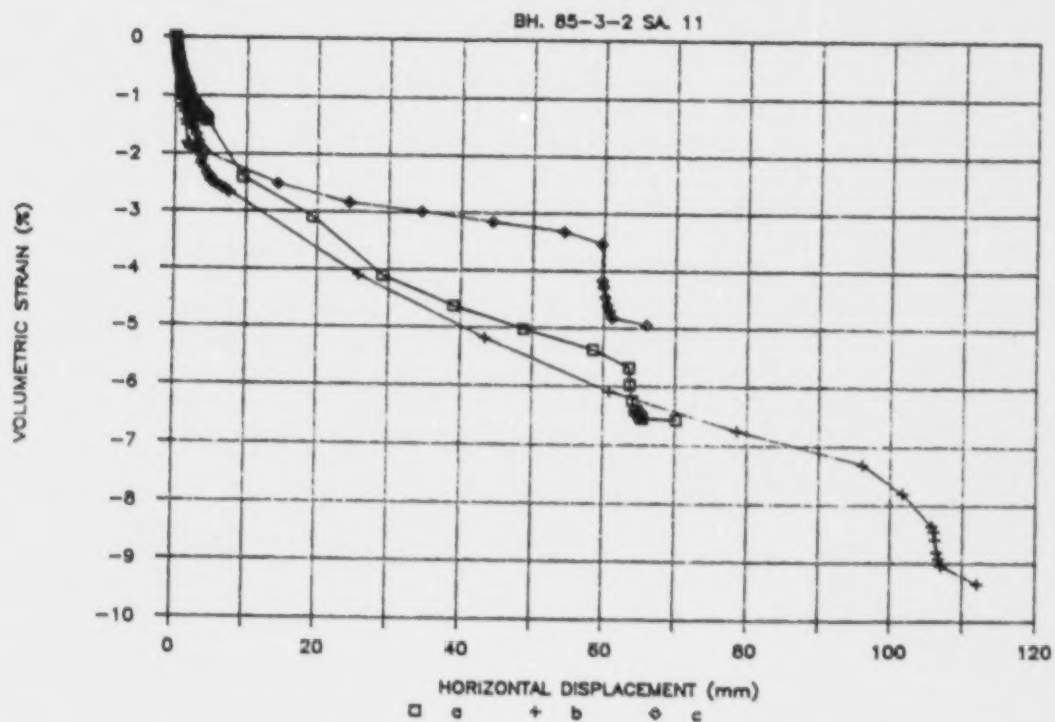
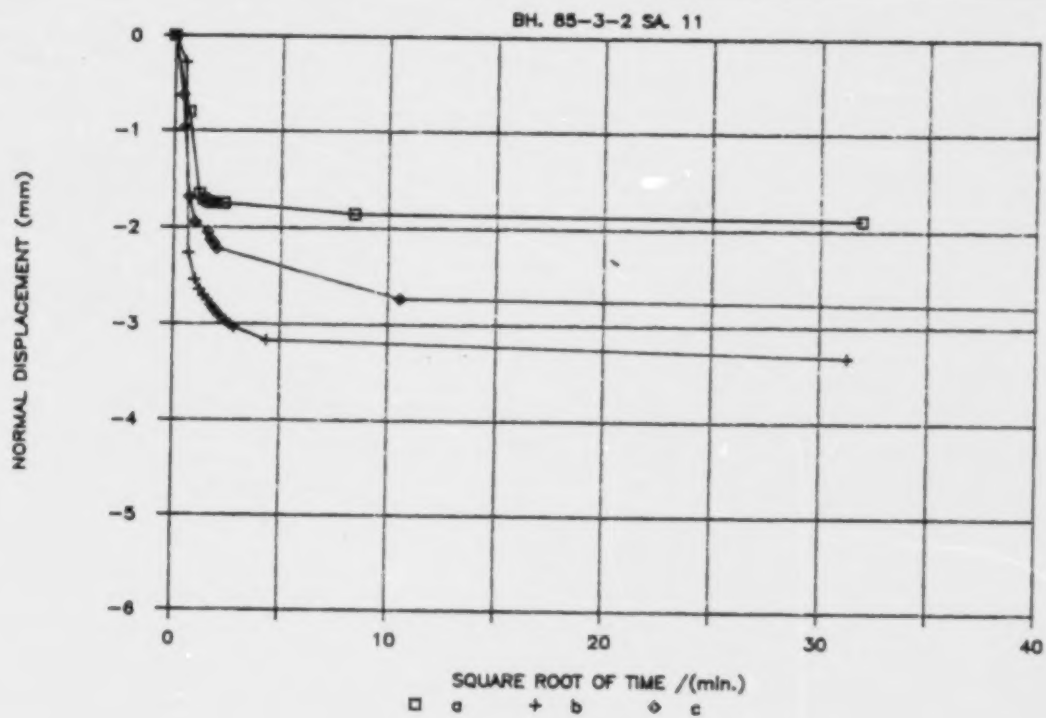
FIGURE 35-2



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CONSOLIDATED DRAINED DIRECT SHEAR TEST
SHEET 3 OF 3

FIGURE 35-3



CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 1 OF 3

FIGURE 36-1

CONSOLIDATED DRAINED DIRECT SHEAR TESTS

TEST NUMBER	A	B	C
BOREHOLE NUMBER	85-3-2	85-3-2	85-3-2
SAMPLE NUMBER	19	19	19
SAMPLE DEPTH, m	24.70	24.80	24.92
SAMPLE HEIGHT, mm	25.20	25.20	25.00
SAMPLE WIDTH, mm	59.50	59.50	59.50
WATER CONTENT, BEFORE CONSOLIDATION, %	26	24	26
NORMAL (CONSOLIDATION) STRESS, kPa	148	300	599
WATER CONTENT, SHEAR PLANE, %	29	25	30
AVERAGE RATE OF STRAIN, %/hr.	0.5	0.5	0.5
TIME TO FAILURE, days	1.5	1.5	1.5
PEAK SHEAR STRESS, kPa	57.4	116.2	220.0
RESIDUAL SHEAR STRESS, kPa, first pass	40.9	58.0	90.8
fifth pass	27.3	51.2	112.7
sixth pass	60.7	118.6	203.5
HORIZONTAL DISPLACEMENT AT PEAK, mm	2.12	2.46	2.94
HORIZONTAL DISPLACEMENT, RESIDUAL, mm			
first pass	14.18	18.37	21.29
fifth pass	52.30	67.74	79.10
sixth pass	63.59	79.51	91.32
NATURAL WATER CONTENT, %	26	24	29
LIQUID LIMIT, w _L	38		
PLASTIC LIMIT, w _p	19		
UNIT WEIGHT, kN/m ³	19.96	20.06	20.15
SAMPLE DESCRIPTION	A. red fissured silty clay with some fine gravel		
	B. same as sample A		
	C. same as sample A		

FAILURE PLANE MATERIAL as above description

DATE March 1986

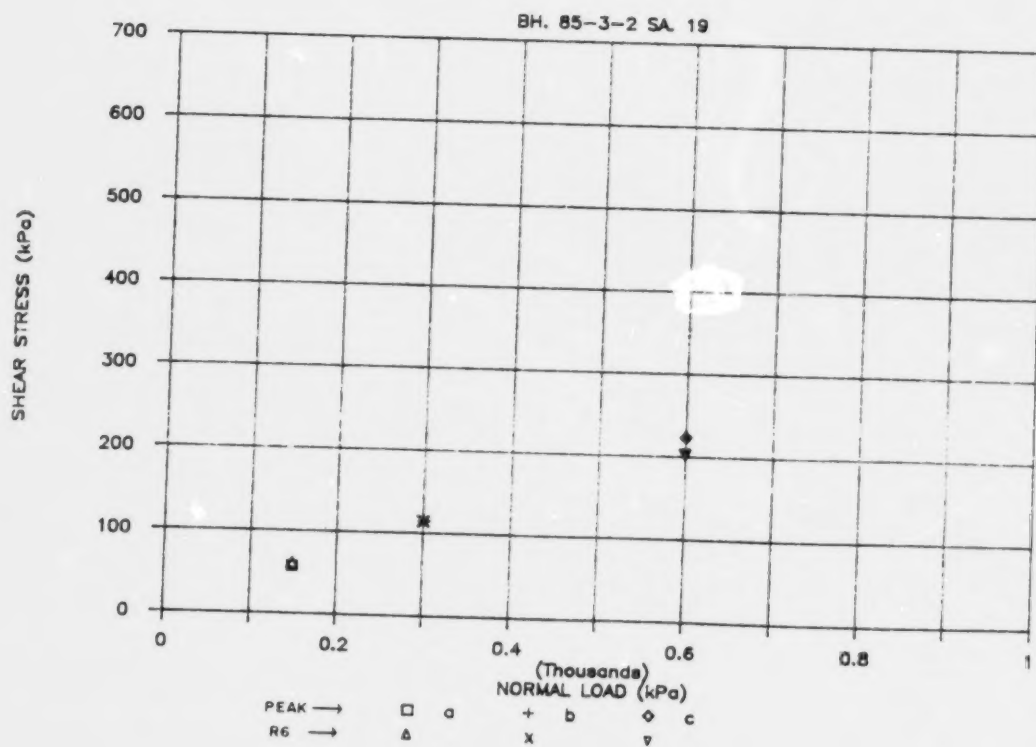
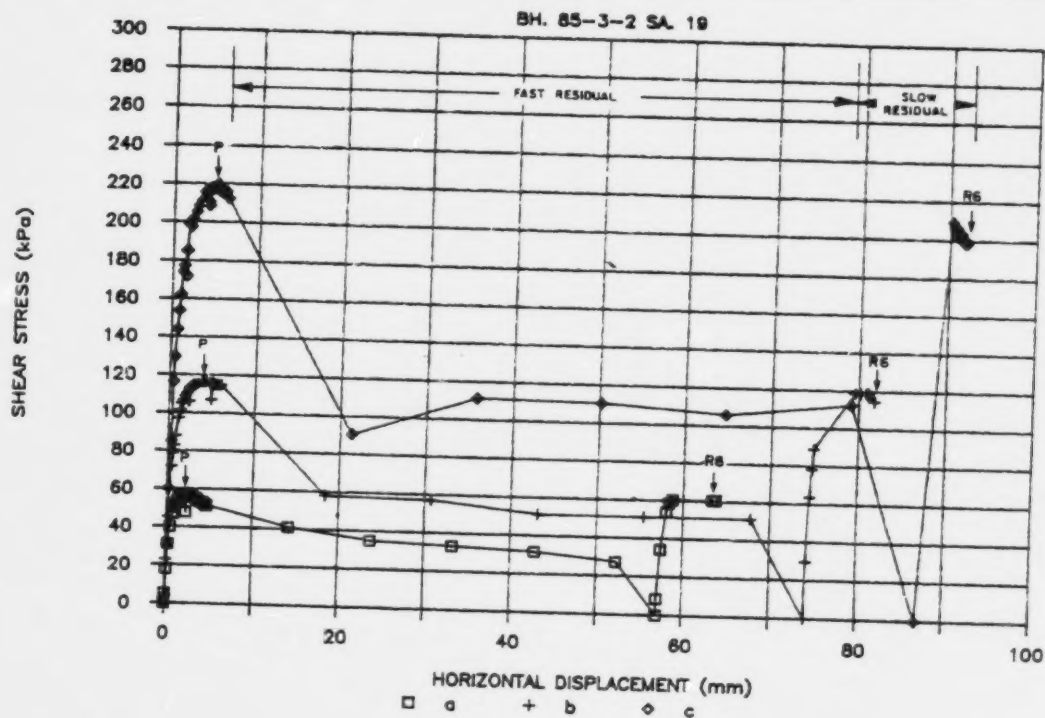
PROJECT 951-1298 (GLAL PROJECT # 85-GT-4)

DATA BY S.A.R.

CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 2 OF 3

FIGURE 36-2

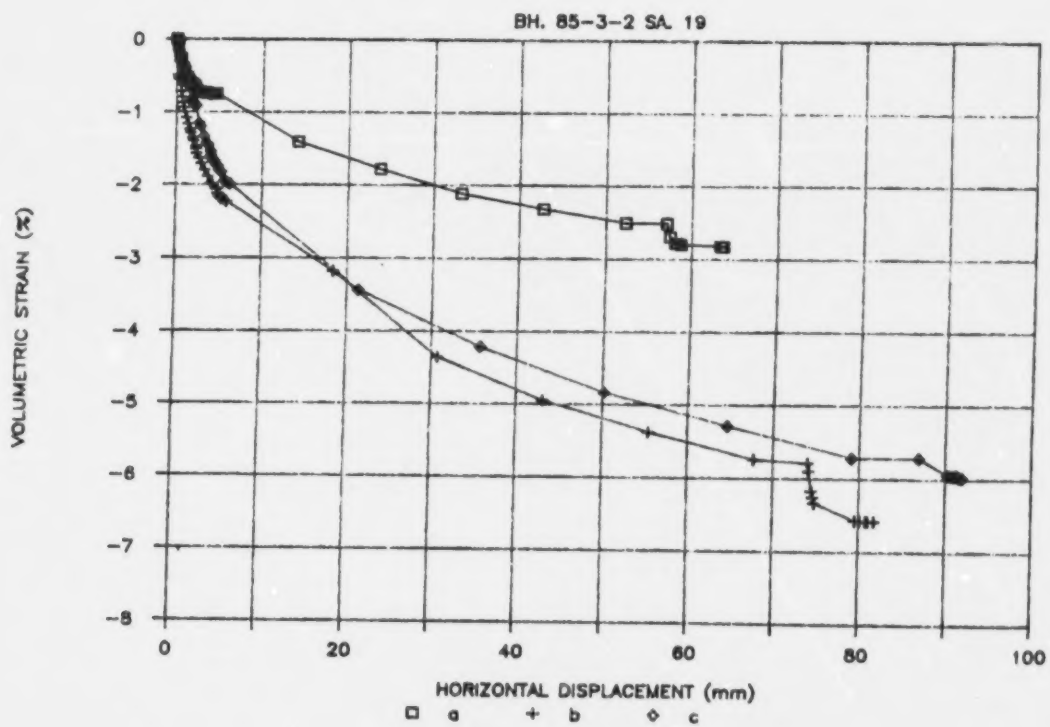
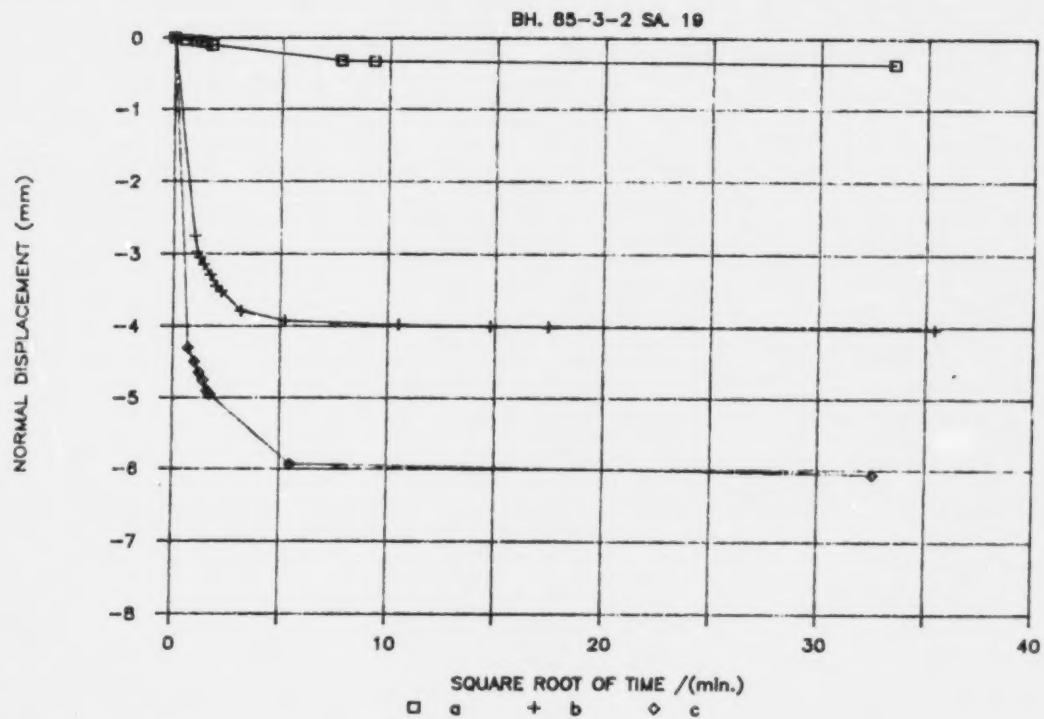


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CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 3 OF 3

FIGURE 36-3



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CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 1 OF 3

FIGURE 37-1

CONSOLIDATED DRAINED DIRECT SHEAR TESTS

TEST NUMBER	A	B	C
BOREHOLE NUMBER	85-10-2	85-10-2	85-10-2
SAMPLE NUMBER	7	7	7
SAMPLE DEPTH, m	6.80	5.89	5.80
SAMPLE HEIGHT, mm	25.20	25.20	25.00
SAMPLE WIDTH, mm	59.50	59.50	59.50
WATER CONTENT, BEFORE CONSOLIDATION, %	19	19	19
NORMAL (CONSOLIDATION) STRESS, kPa	300	599	999
WATER CONTENT, SHEAR PLANE, %	26	22	23
AVERAGE RATE OF STRAIN, %/hr.	0.5	0.5	0.5
TIME TO FAILURE, days	1.5	1.5	1.5
PEAK SHEAR STRESS, kPa	139.1	234.8	397.4
RESIDUAL SHEAR STRESS, kPa, first pass	115.2	165.1	300.9
fifth pass	72.5	183.7	296.7
sixth pass	135.6	229.9	373.1
HORIZONTAL DISPLACEMENT AT PEAK, mm	3.58	6.42	4.60
HORIZONTAL DISPLACEMENT, RESIDUAL, mm			
first pass	23.04	23.74	20.40
fifth pass	85.30	89.09	78.74
sixth pass	100.49	104.96	93.61
NATURAL WATER CONTENT, %	19	19	19
LIQUID LIMIT, w _L			36
PLASTIC LIMIT, w _p			19
UNIT WEIGHT, kN/m ³	20.61	20.61	20.36
SAMPLE DESCRIPTION	A, red fissured silty clay with trace fine gravel		
	B, same as sample A		
	C, same as sample A		

FAILURE PLANE MATERIAL as above description

DATE April, 1986

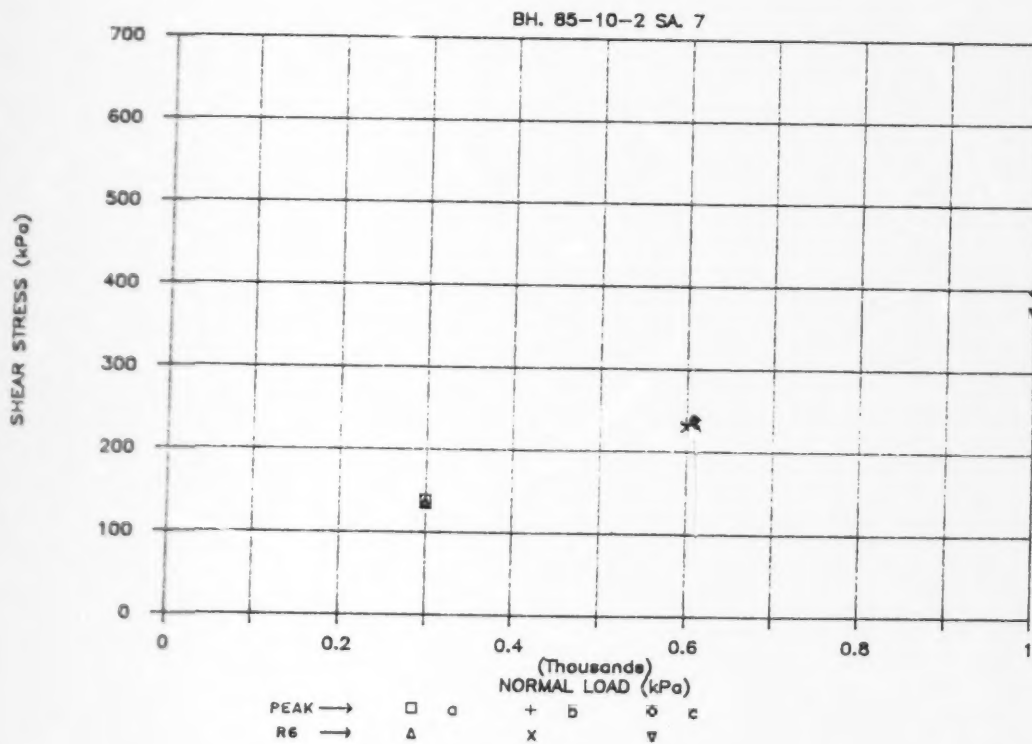
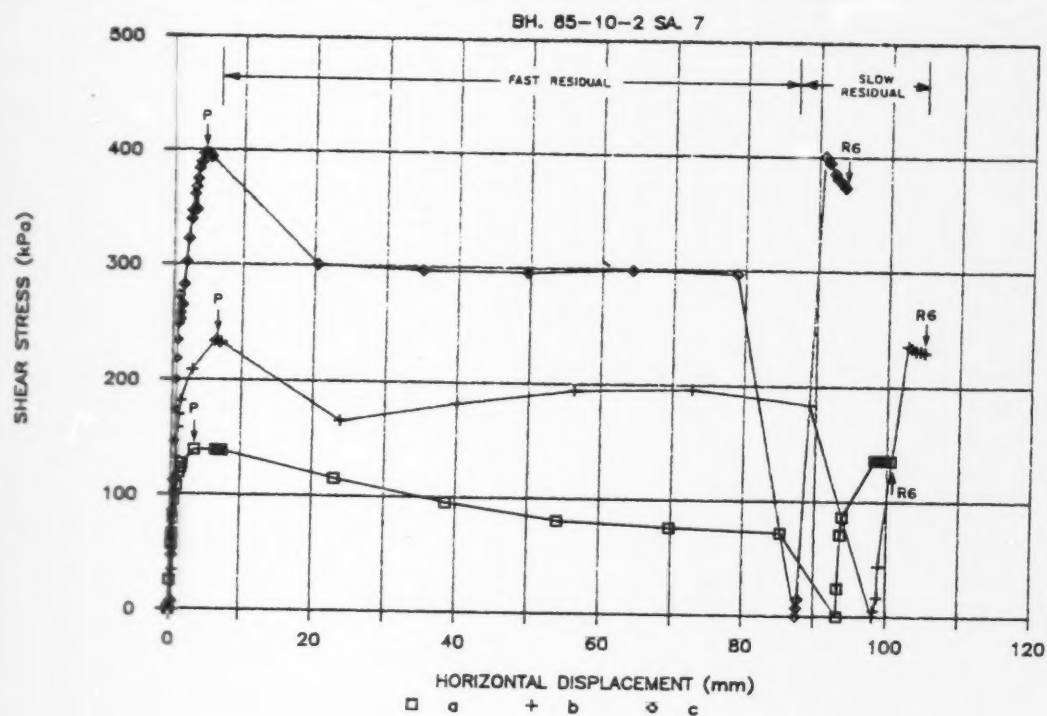
PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

DATA BY F.A.R.

CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 2 OF 3

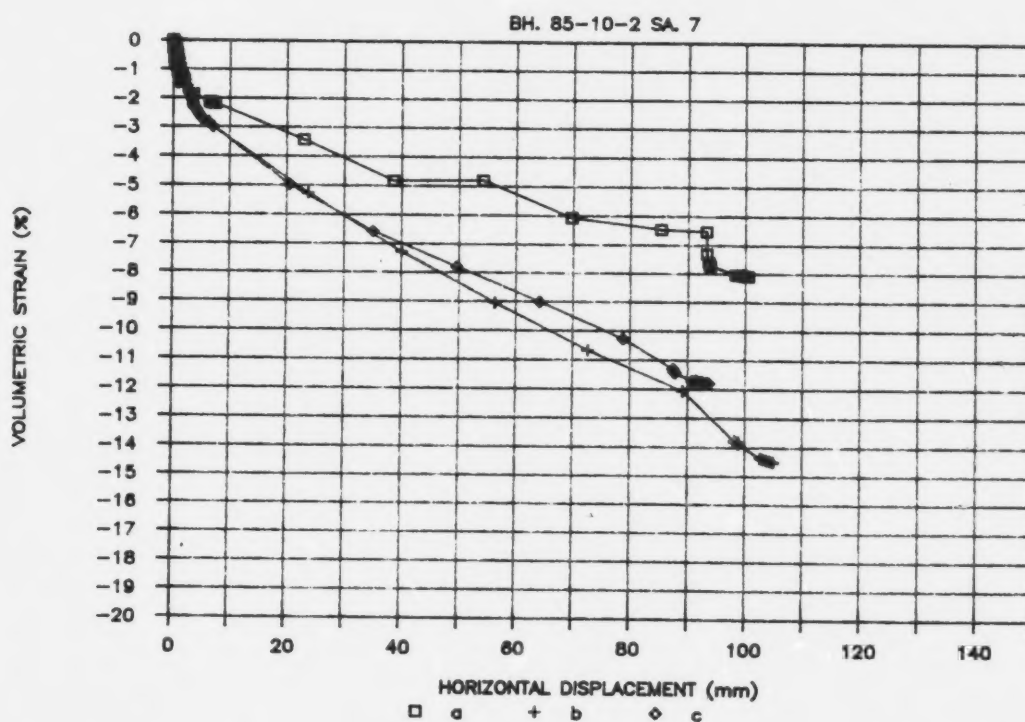
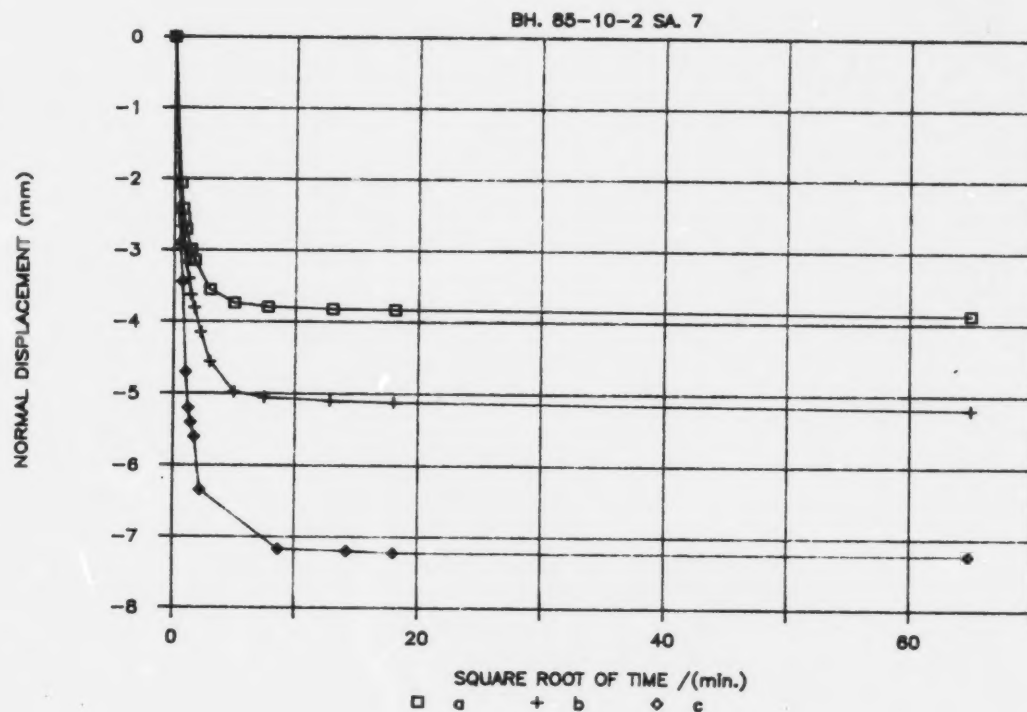
FIGURE 37-2



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CONSOLIDATED DRAINED DIRECT SHEAR TEST
SHEET 3 OF 3

FIGURE 37-3



CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 1 OF 3

FIGURE 38-1

CONSOLIDATED DRAINED DIRECT SHEAR TESTS

TEST NUMBER	A	B	C
BOREHOLE NUMBER	85-10-2	85-10-2	85-10-2
SAMPLE NUMBER	20	20	20
SAMPLE DEPTH, m	20.84	20.77	20.65
SAMPLE HEIGHT, mm	25.20	25.20	25.00
SAMPLE WIDTH, mm	59.50	59.50	59.50
WATER CONTENT, BEFORE CONSOLIDATION, %	18	18	17
NORMAL (CONSOLIDATION) STRESS, kPa	199	400	650
WATER CONTENT, SHEAR PLANE, %	16	17	21
AVERAGE RATE OF STRAIN, %/hr.	0.5	0.5	0.5
TIME TO FAILURE, days	1.5	1.5	1.5
PEAK SHEAR STRESS, kPa	112.9	222.7	400.5
RESIDUAL SHEAR STRESS, kPa, first pass	74.2	149.3	325.6
fifth pass	78.5	179.2	344.6
sixth pass	120.3	226.1	336.8
HORIZONTAL DISPLACEMENT AT PEAK, mm	7.12	6.40	7.09
HORIZONTAL DISPLACEMENT, RESIDUAL, mm			
first pass	22.00	22.45	23.30
fifth pass	81.11	83.18	87.42
sixth pass	95.15	97.84	103.39
NATURAL WATER CONTENT, %	18	18	17
LIQUID LIMIT, wl		25	
PLASTIC LIMIT, wp		10	
UNIT WEIGHT, kN/m ³	21.21	20.82	21.21
SAMPLE DESCRIPTION	A. red fissured silty clay with trace fine gravel		
	B. same as sample A		
	C. same as sample A		

FAILURE PLANE MATERIAL as above description

DATE April, 1986

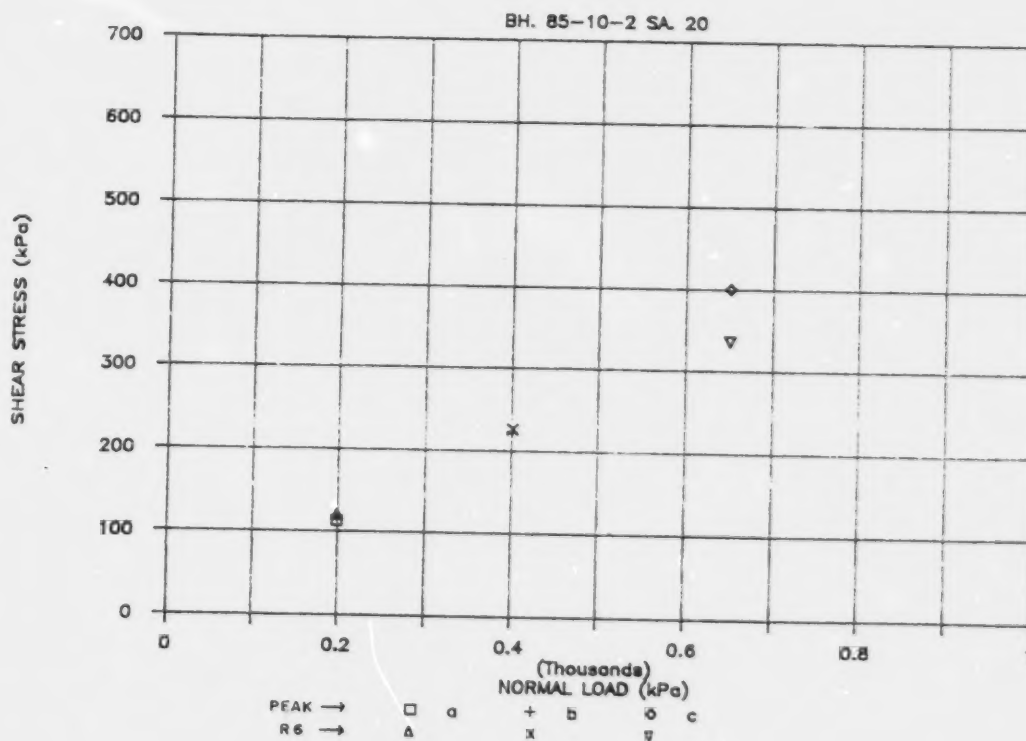
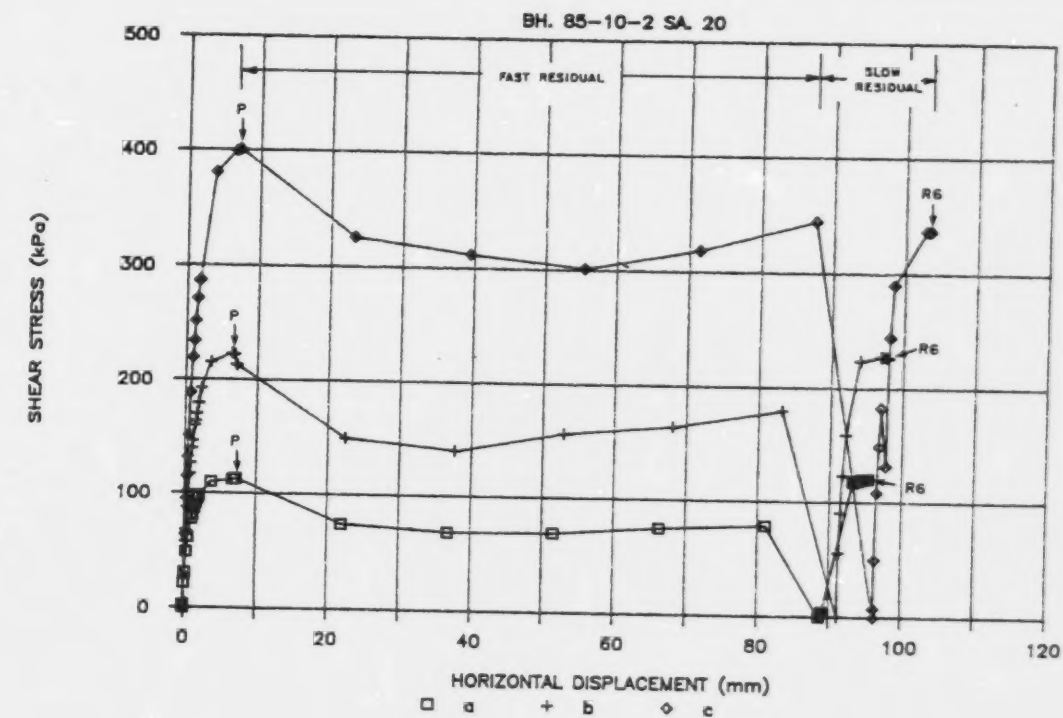
PROJECT 851-1298 (GLAL PROJECT # 95-GT-4)

DATA BY F.A.R.

CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 2 OF 3

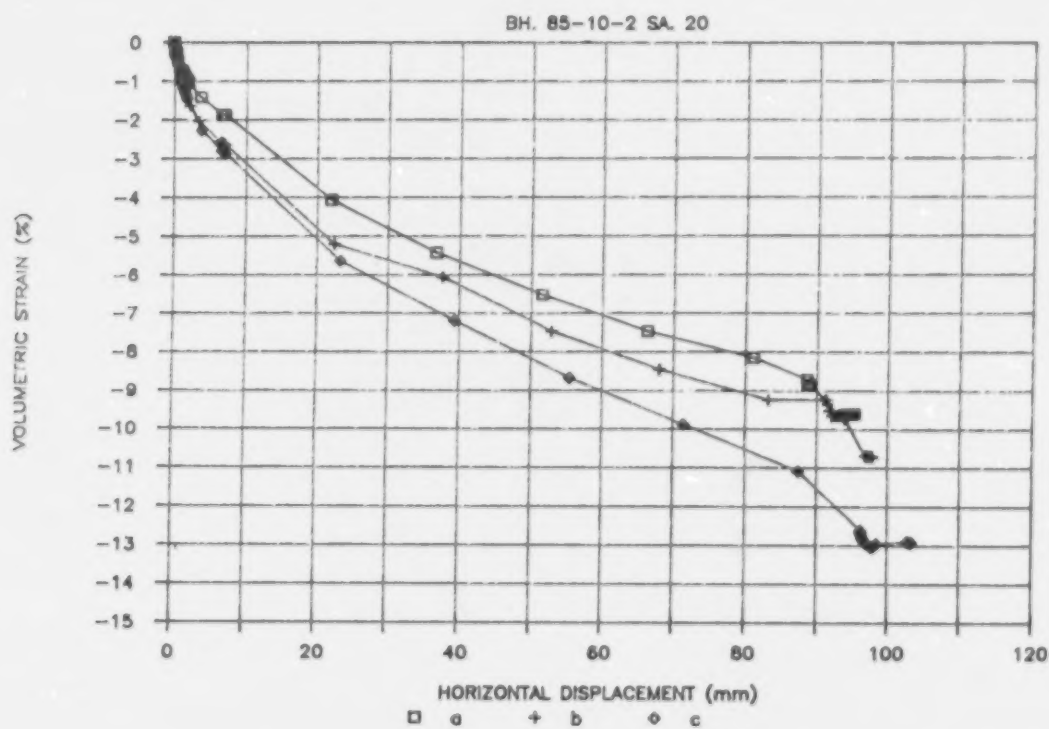
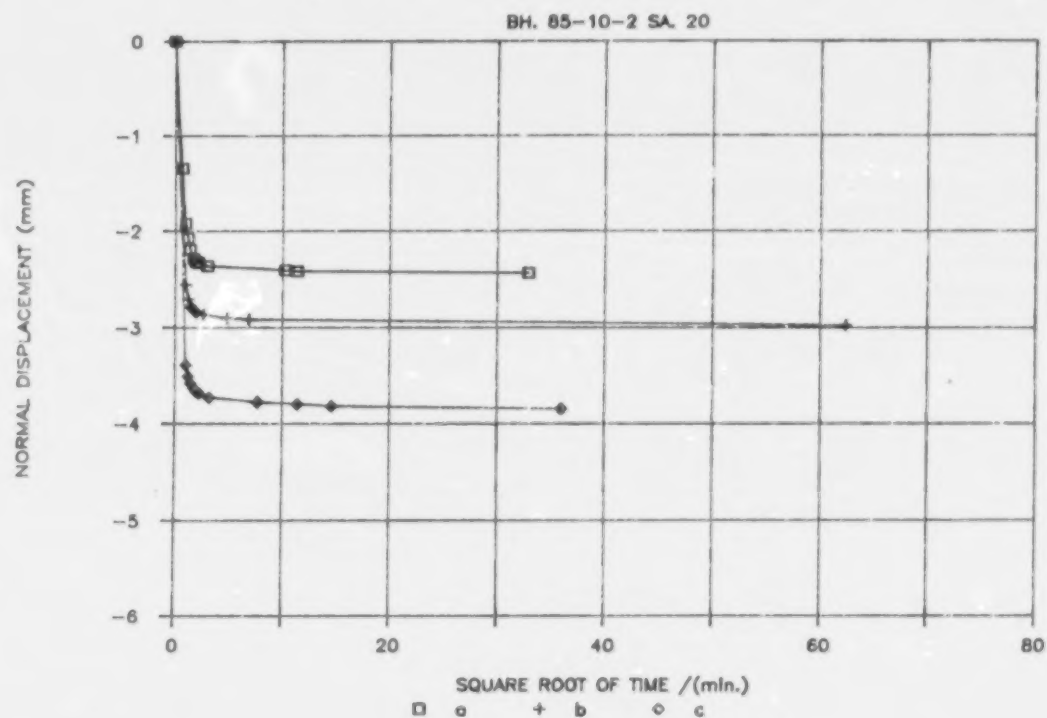
FIGURE 38-2



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CONSOLIDATED DRAINED DIRECT SHEAR TEST
SHEET 3 OF 3

FIGURE 38-3



CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 1 OF 3

FIGURE 39-1

CONSOLIDATED DRAINED DIRECT SHEAR TESTS

TEST NUMBER	A	B	C
BOREHOLE NUMBER	85-10-2	85-10-2	85-10-2
SAMPLE NUMBER	28	28	28
SAMPLE DEPTH, m	29.70	29.75	29.80
SAMPLE HEIGHT, mm	25.20	25.20	25.00
SAMPLE WIDTH, mm	59.50	59.50	59.50
WATER CONTENT, BEFORE CONSOLIDATION, %	35	34	36
NORMAL (CONSOLIDATION) STRESS, kPa	303	500	700
WATER CONTENT, SHEAR PLANE, %	38	21	24
AVERAGE RATE OF STRAIN, %/hr.	0.5	0.5	0.5
TIME TO FAILURE, days	1.5	1.5	1.5
PEAK SHEAR STRESS, kPa	96.7	176.5	214.0
RESIDUAL SHEAR STRESS, kPa, first pass	32.3	110.9	117.6
fifth pass	75.0	67.4	107.3
sixth pass	98.5	160.6	155.2
HORIZONTAL DISPLACEMENT AT PEAK, mm	5.85	6.61	3.12
HORIZONTAL DISPLACEMENT, RESIDUAL, mm			
first pass	23.28	23.14	23.70
fifth pass	86.08	85.64	98.47
sixth pass	100.67	101.13	103.98
NATURAL WATER CONTENT, %	35	34	36
LIQUID LIMIT, w _L	49		
PLASTIC LIMIT, w _p	25		
UNIT WEIGHT, kN/m ³	18.39	20.96	19.26
SAMPLE DESCRIPTION	A, red fissured silty clay with trace fine gravel		
	B, same as sample A		
	C, same as sample A		

FAILURE PLANE MATERIAL as above description

DATE April, 1986

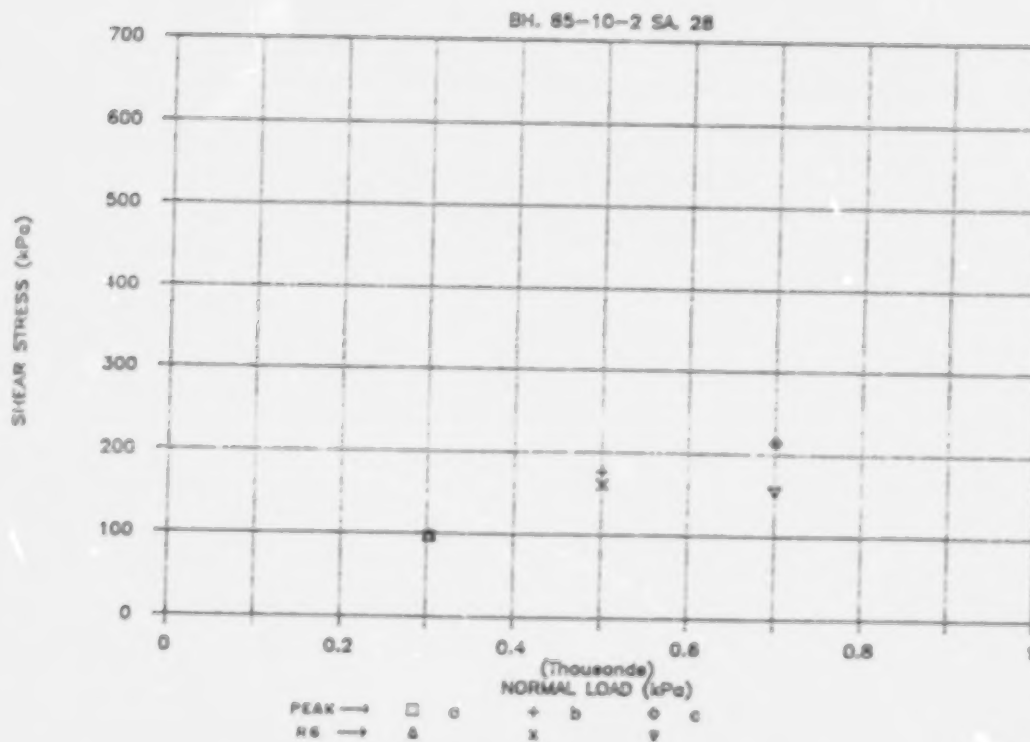
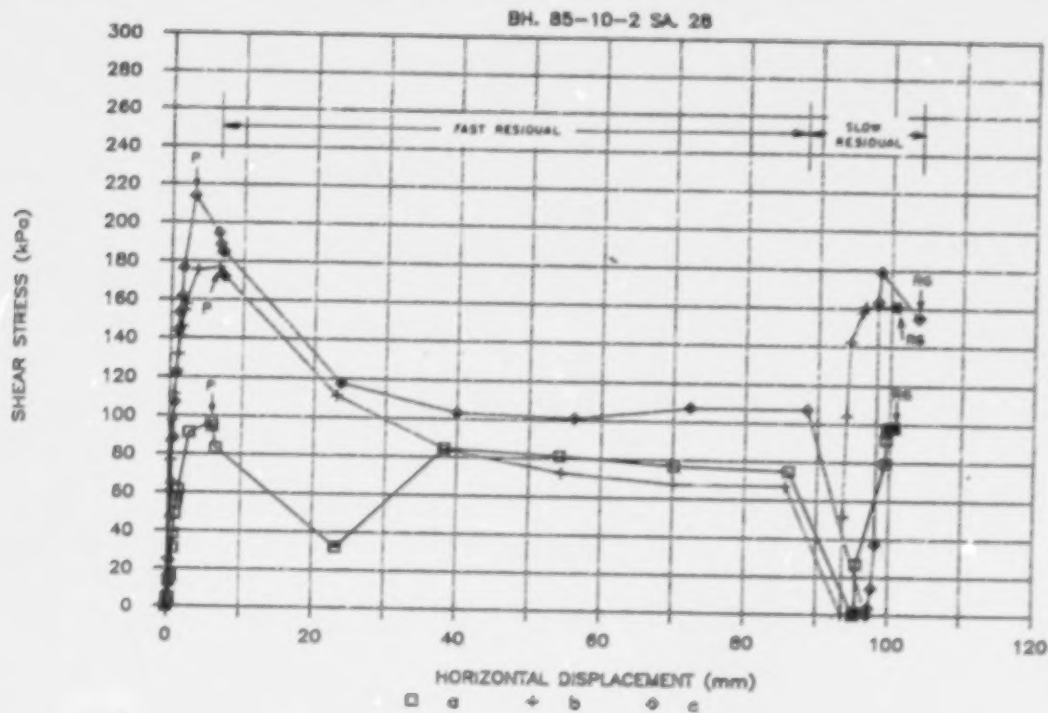
PROJECT 951-1029, ISLAL Project # 85-8T-41

DATA BY F.A.R.

CONSOLIDATED DRAINED DIRECT SHEAR TEST

SHEET 2 OF 3

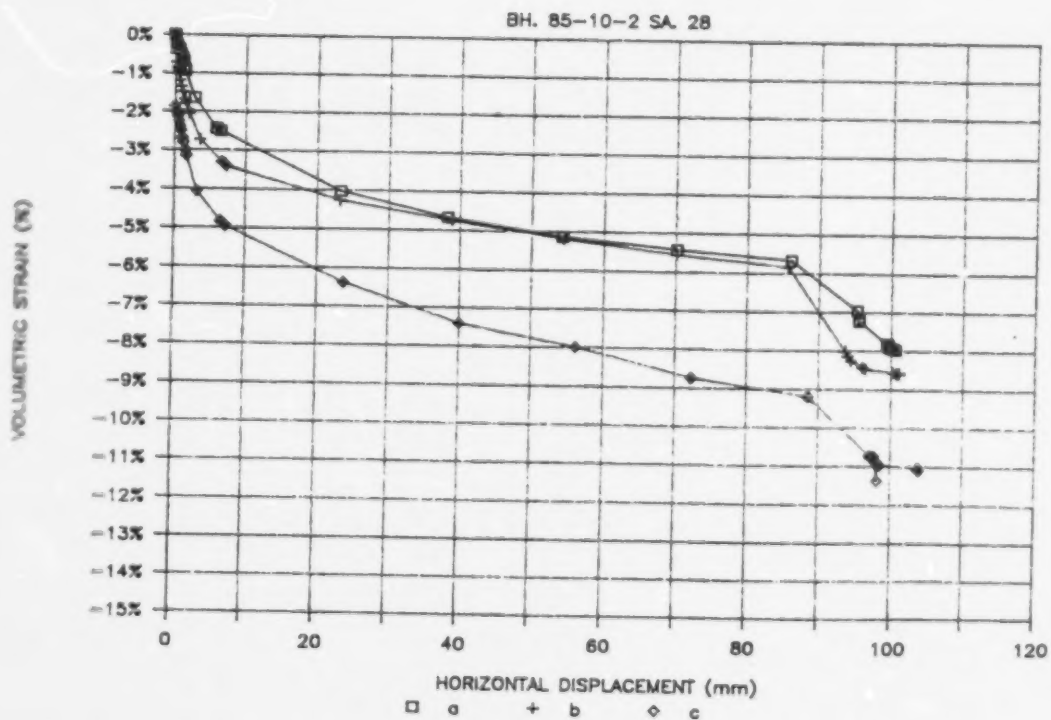
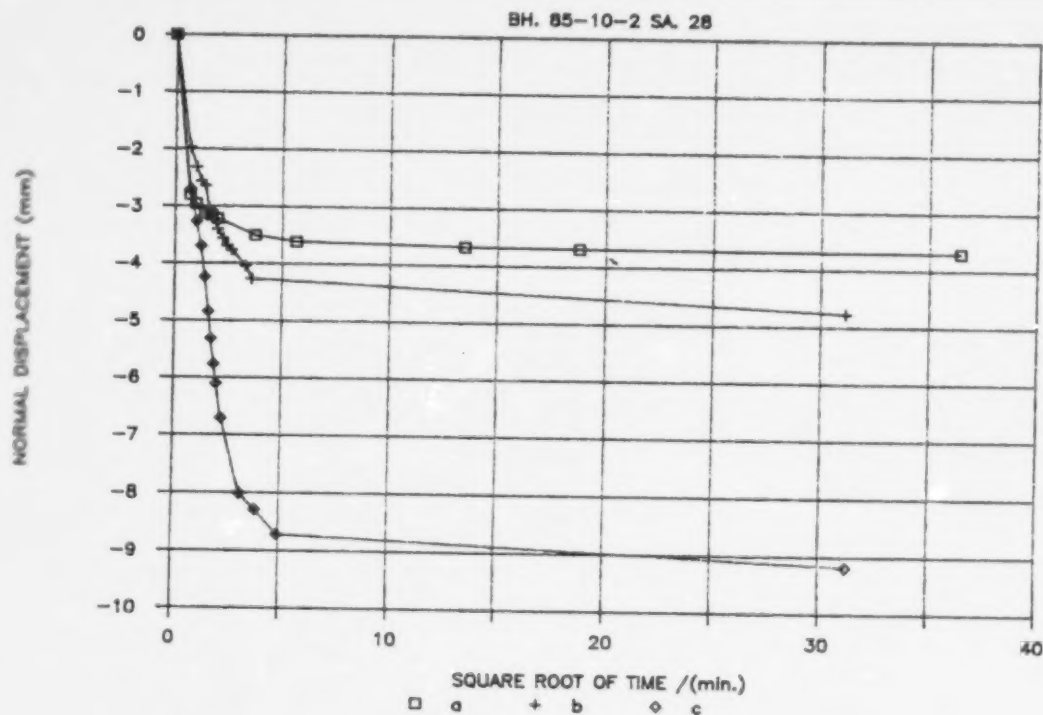
FIGURE 39-2



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CONSOLIDATED DRAINED DIRECT SHEAR TEST
SHEET 3 OF 3

FIGURE 39-3



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851-1298

CONSOLIDATION

FIGURES 40-1 to 45-2

CONSOLIDATION
SHEET 1 OF 2

FIGURE 40-1

PROJECT 851-1298 SPECIFIC GRAVITY 2.78 DATE ST. 86-01-27
SAMPLE BH.85-5-2 SA.6 DRY WEIGHT, gm 90.44 DATE FN. 86-02-05
AREA(mm²) 3166.9 SOLIDS HT. mm (2HS) 10.273

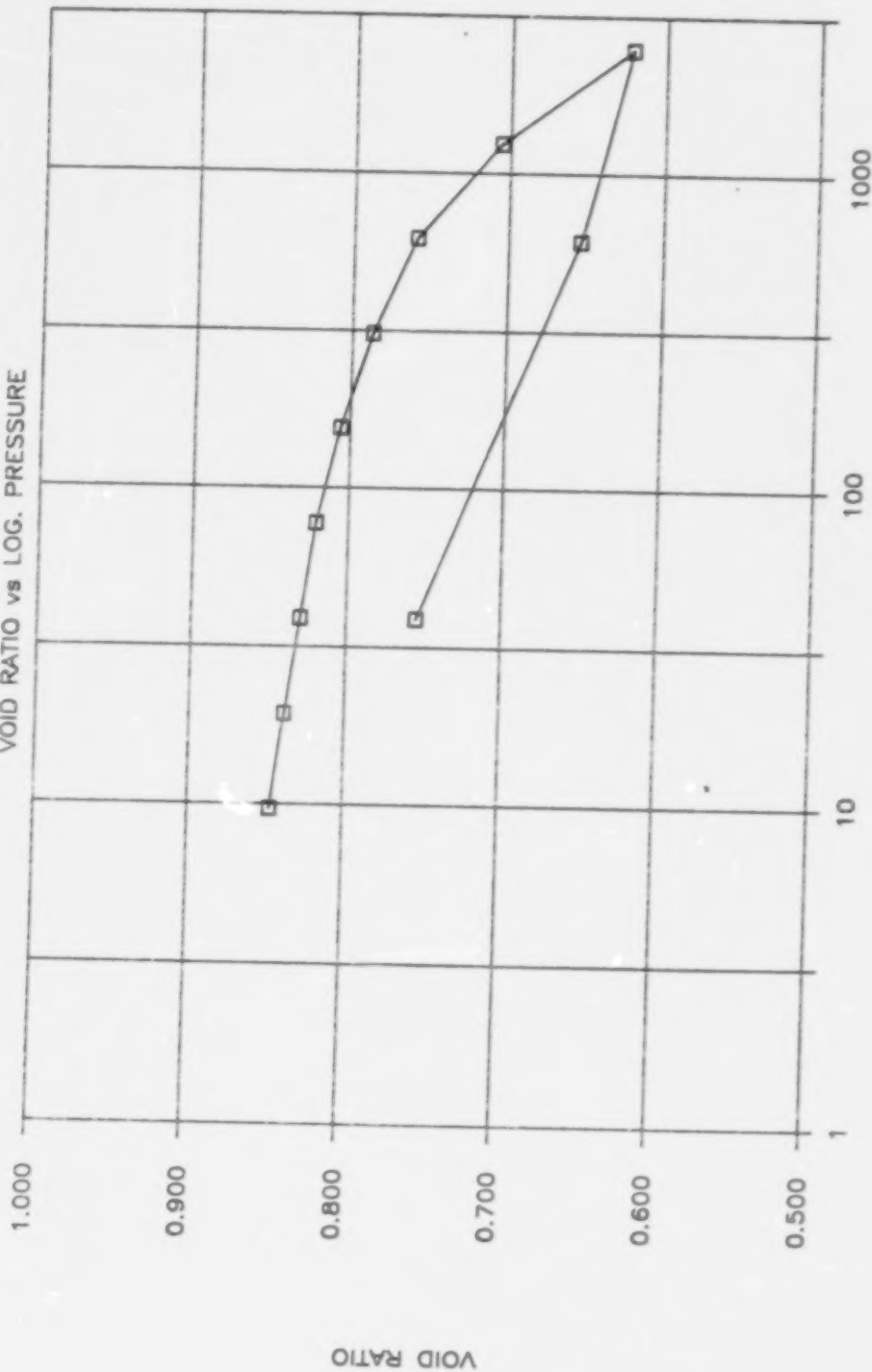
Applied Load kPa	Corr. Height mm	Void Ratio	Average Height mm	t ₉₀ sec	C _v cm ² / s t ₉₀
0.00	19.050	0.854	19.050	swelling	
9.65	18.970	0.847	19.010	swelling	
19.31	18.884	0.838	18.927	228	3.33E-03
38.62	18.792	0.829	18.838	180	4.18E-03
77.23	18.701	0.820	18.746	150	4.97E-03
154.46	18.551	0.806	18.626	156	4.72E-03
308.92	18.351	0.786	18.451	258	2.80E-03
617.84	18.064	0.758	18.207	180	3.91E-03
1235.68	17.516	0.705	17.790	240	2.80E-03
2471.36	16.650	0.622	17.087		
607.84	16.986	0.653	16.822		
38.62	18.022	0.754	17.504		

WATER CONTENT %, initial	30	LIQUID LIMIT %	50
WATER CONTENT %, final	30	PLASTIC LIMIT %	28
UNIT WEIGHT, kN/m ³	19.05		

PROJECT 851-1298 (GLAL PROJECT # 85-ST-4)

CONSOLIDATION TEST

VOID RATIO vs LOG. PRESSURE



□ BH 85-5-2 / SA 6

CONSOLIDATION
SHEET 1 OF 2

FIGURE 41-1

PROJECT 851-1298 SPECIFIC GRAVITY 2.78 DATE ST. 86-01-09
SAMPLE BH.85-5-2 SA.10 DRY WEIGHT, gm 109.06 DATE FN. 86-02-16
AREA(mm2) 3166.9 SOLIDS HT.mm (2HS) 12.388

Applied Load kPa	Corr. Height mm	Void Ratio	Average Height mm	t90 sec	Cv cm sq / s t90
0.00	19.050	0.538	19.050	150	5.13E-03
9.65	18.993	0.533	19.021	216	3.55E-03
19.31	18.960	0.531	18.976	156	4.89E-03
38.62	18.921	0.527	18.940	108	7.04E-03
77.23	18.861	0.523	18.891	96	7.88E-03
154.46	18.780	0.516	18.820	90	8.34E-03
308.92	18.654	0.506	18.717	72	1.03E-02
617.84	18.384	0.484	18.519	138	5.27E-03
1235.70	17.925	0.447	18.154	108	6.47E-03
2471.36	17.337	0.400	17.631		
617.84	17.473	0.411	17.405		
9.65	18.037	0.456	17.755		

WATER CONTENT %, initial 19 LIQUID LIMIT % 27
WATER CONTENT %, final 17 PLASTIC LIMIT % 18
UNIT WEIGHT, kN/m3 21.05

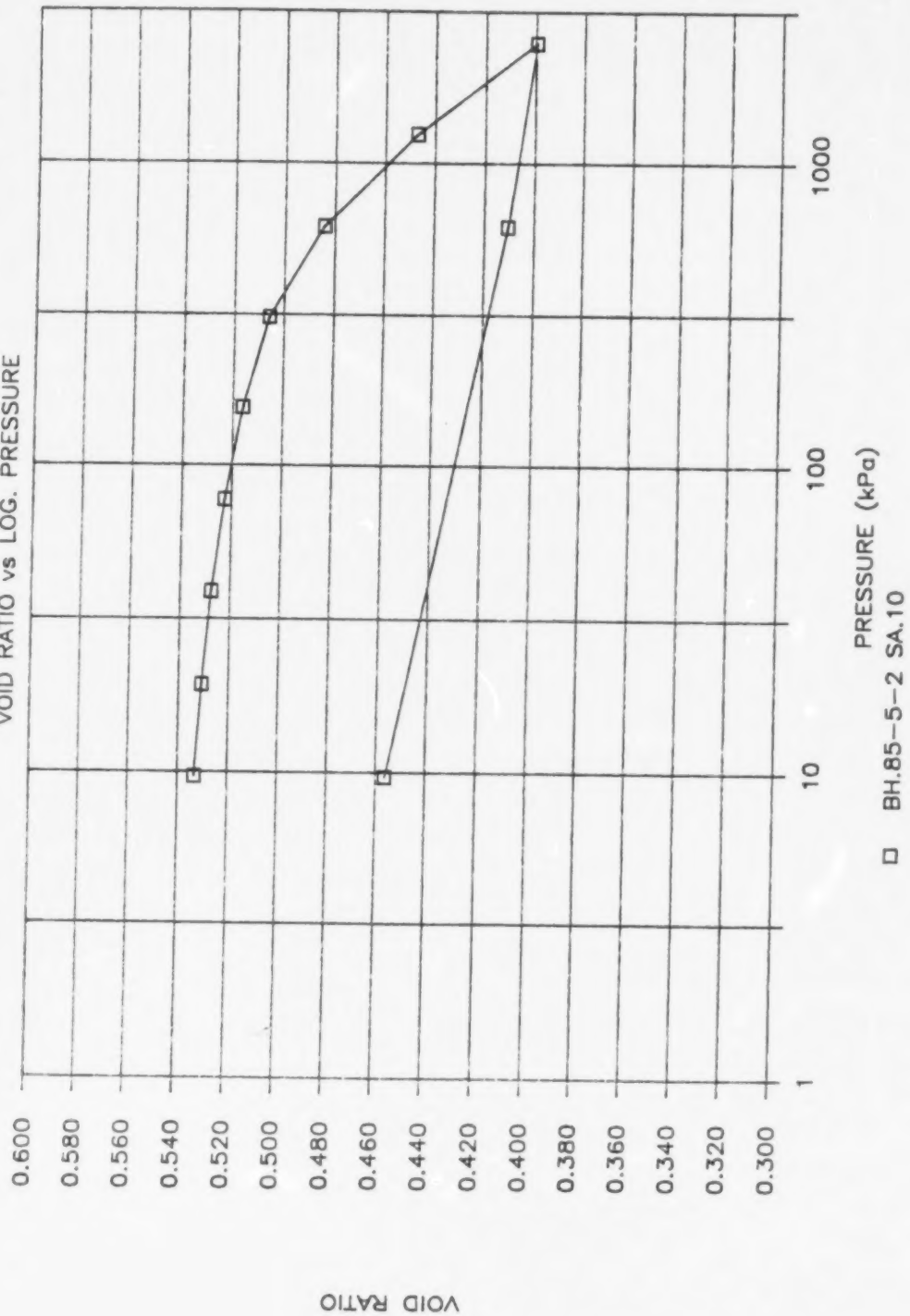
PROJECT 851-1298 (GLAL PROJECT # 85-6T-4)

CONSOLIDATION
SHEET 2 OF 2

FIGURE 41-2

CONSOLIDATION TEST

VOID RATIO vs LOG. PRESSURE



CONSOLIDATION

SHEET 1 OF 2

FIGURE 42-1

PROJECT 851-1298 SPECIFIC GRAVITY 2.78 DATE ST. 86-01-21
 SAMPLE BH.85-5-2 SA.18 DRY WEIGHT.gm 99.81 DATE FN. 86-02-27
 AREA(mm2) 3166.9 SOLIDS HT.mm (2HS) 11.337

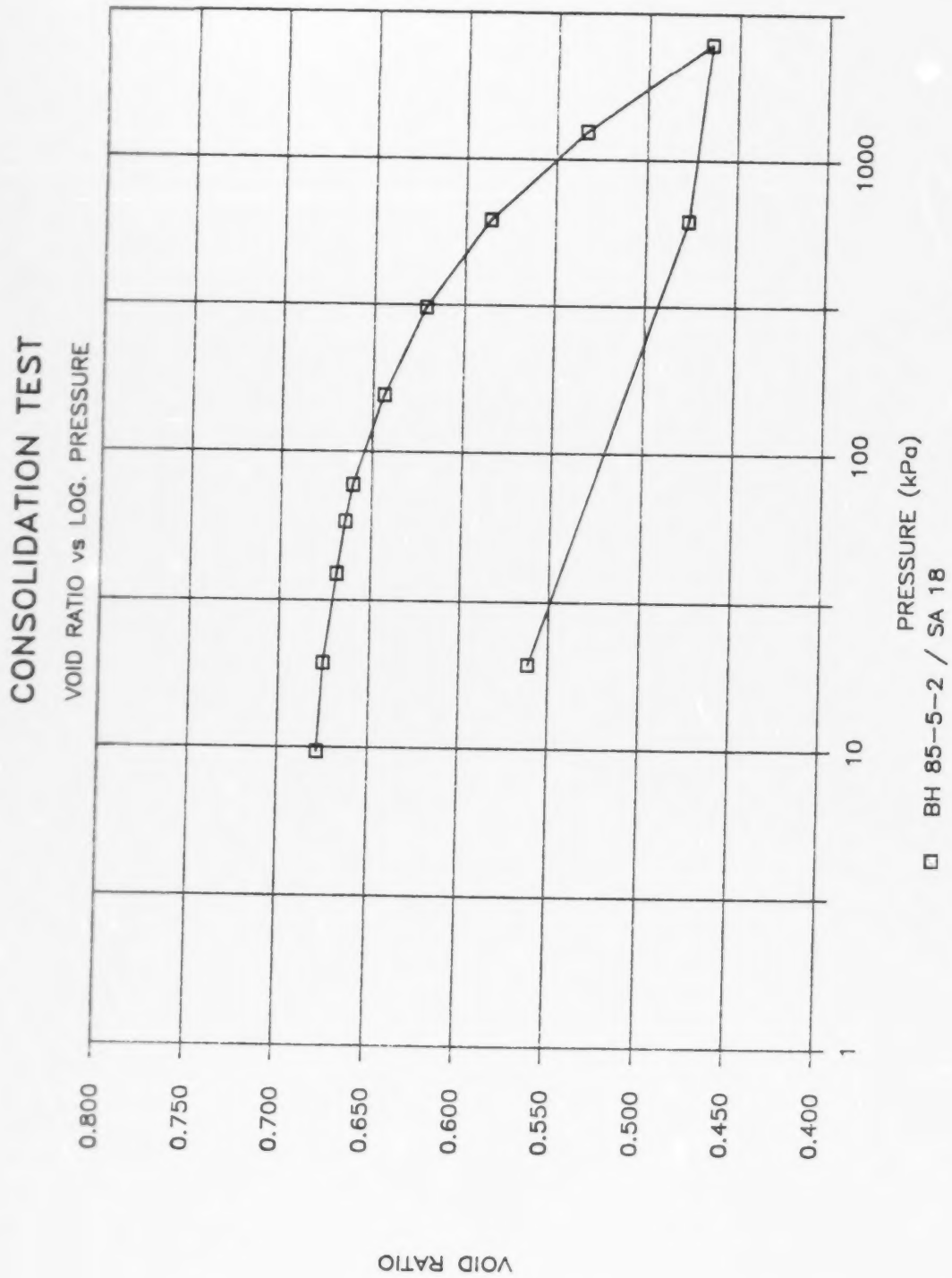
Applied Load kPa	Corr. Height mm	Void Ratio	Average Height mm	t90 sec	Cv cm2 / s t90
0.00	19.050	0.680	19.050	swelling	
9.65	19.022	0.678	19.036	192	4.00E-03
19.31	18.991	0.675	19.006	240	3.19E-03
38.62	18.914	0.668	18.952	216	3.53E-03
57.92	18.866	0.664	18.898	306	2.47E-03
77.23	18.823	0.660	18.844	216	3.49E-03
154.46	18.634	0.644	18.728	210	3.54E-03
308.92	18.379	0.621	18.507	204	3.56E-03
617.84	17.980	0.586	18.180	168	4.17E-03
1235.68	17.381	0.533	17.680	180	3.68E-03
2471.36	16.605	0.465	16.993		
617.84	16.739	0.476	16.672		
19.31	17.698	0.561	17.218		

WATER CONTENT %, initial 24 LIQUID LIMIT % 37
 WATER CONTENT %, final 22 PLASTIC LIMIT % 28
 UNIT WEIGHT,kN/m3 20.19

PROJECT 851-1298 (GLAL PROJECT # 85-6T-4)

CONSOLIDATION
SHEET 2 OF 2

FIGURE 42-2



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CONSOLIDATION
SHEET 1 OF 2

FIGURE 43-1

PROJECT 851-1298 SPECIFIC GRAVITY 2.78 DATE ST. 86-01-09
 SAMPLE BH.85-5-2 SA.23 DRY WEIGHT, gm 99.68 DATE FN. 86-02-15
 AREA(mm²) 3166.9 SOLIDS HT. mm (2HS) 11.322

Applied Load kPa	Corr. Height mm	Void Ratio	Average Height mm	t ₉₀ sec	C _v cm ² /s t ₉₀
0.00	19.050	0.682	19.050	swelling	
9.65	19.046	0.682	19.048	swelling	
19.31	19.022	0.680	19.034	132	5.82E-03
38.62	18.957	0.674	18.989	246	3.11E-03
57.92	18.901	0.669	18.929	228	3.33E-03
77.23	18.850	0.665	18.875	150	5.04E-03
154.46	18.644	0.647	18.747	204	3.65E-03
308.92	18.373	0.623	18.508	222	3.27E-03
617.84	17.998	0.590	18.185	210	3.34E-03
1235.68	17.404	0.537	17.701	156	4.26E-03
2471.36	16.707	0.476	17.055		
617.84	16.837	0.487	16.772		
19.31	17.943	0.585	17.390		

WATER CONTENT %, initial	25	LIQUID LIMIT %	37
WATER CONTENT %, final	22	PLASTIC LIMIT %	21
UNIT WEIGHT, kN/m ³	20.17		

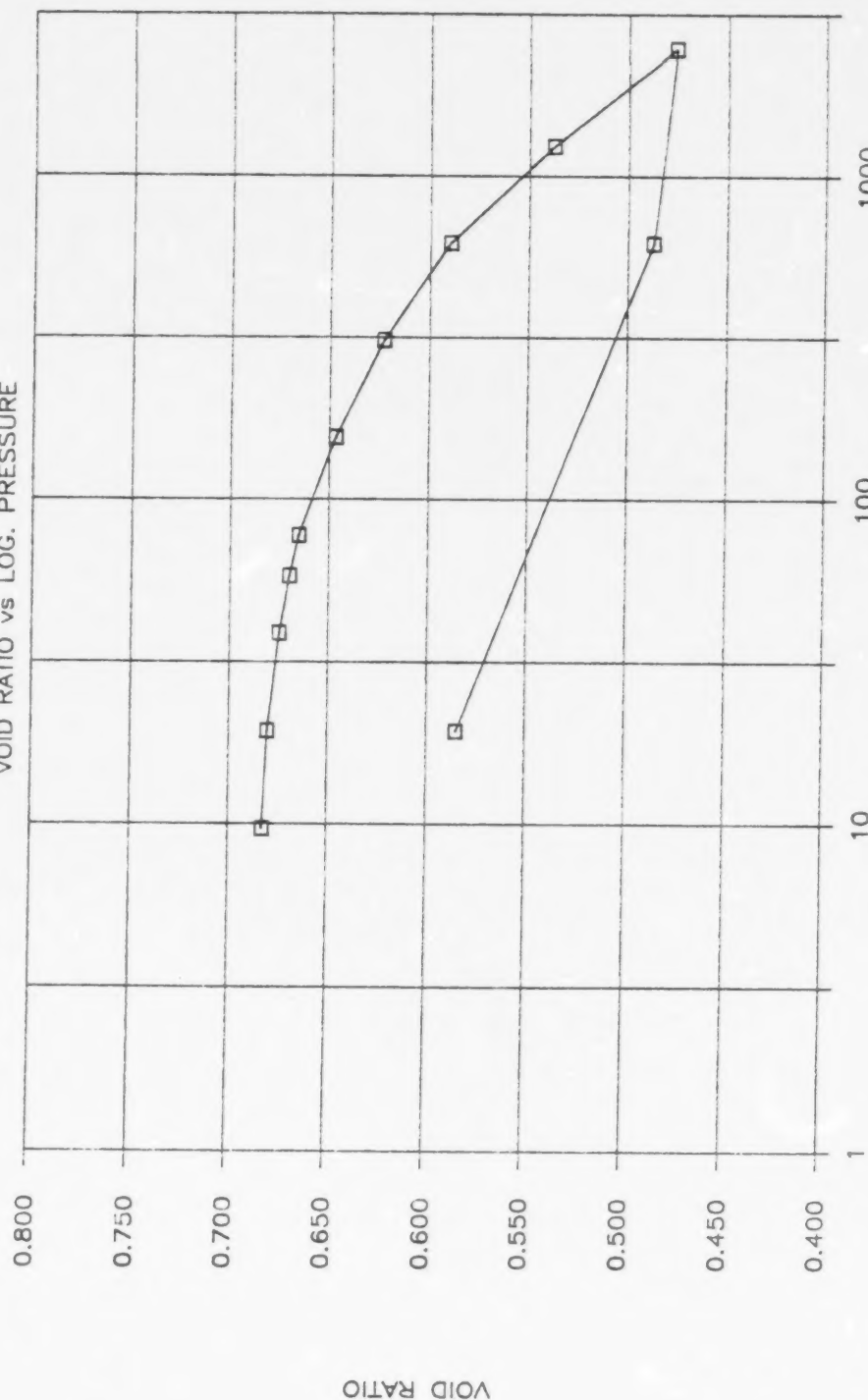
PROJECT 851-1298 (GLAL PROJECT # 85-6T-4)

CONSOLIDATION
SHEET 2 OF 2

FIGURE 43-2

CONSOLIDATION TEST

VOID RATIO vs LOG. PRESSURE



□ BH 85-5-2 / SA 23

CONSOLIDATION
SHEET 1 OF 2

FIGURE 44-1

PROJECT 851-1298 SPECIFIC GRAVITY 2.78 DATE ST. 86-01-09
 SAMPLE BH.85-5-2 SA.26 DRY WEIGHT, gm 85.15 DATE FN. 86-02-15
 AREA(mm²) 3166.9 SOLIDS HT. mm (2HS) 9.672

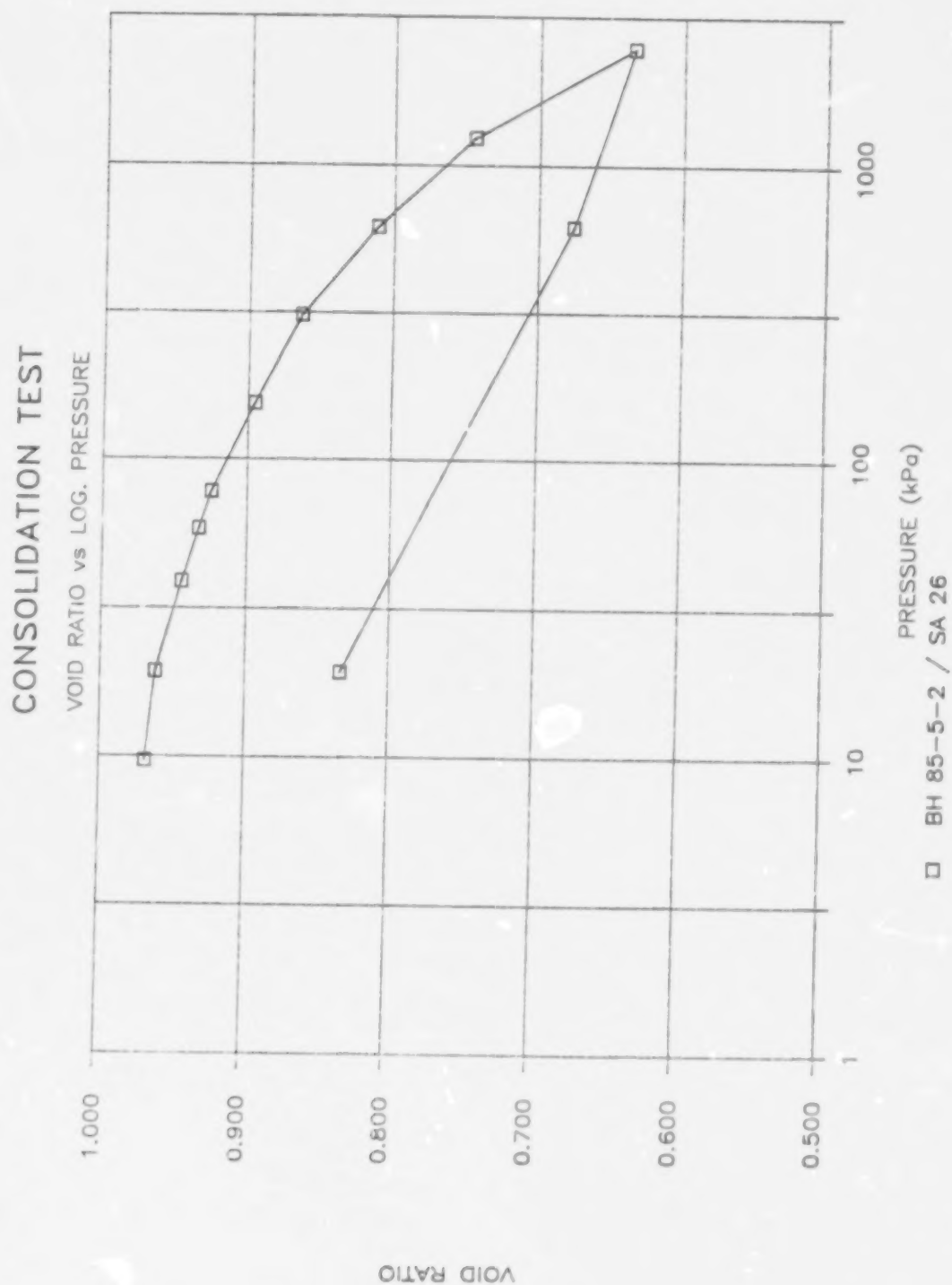
Applied Load kPa	Corr. Height mm	Void Ratio	Average Height mm	t ₉₀ sec	C _v cm ² / s t ₉₀
0.00	19.050	0.970	19.050		
9.65	19.030	0.968	19.040	114	6.74E-03
19.31	18.968	0.961	18.999	300	2.55E-03
38.62	18.802	0.944	18.885	138	5.48E-03
57.92	18.692	0.933	18.747	1080	6.90E-04
77.23	18.614	0.925	18.653	246	3.00E-03
154.46	18.327	0.895	18.470	318	2.27E-03
308.92	18.016	0.863	18.171	360	1.94E-03
617.84	17.513	0.811	17.764	330	2.03E-03
1235.68	16.871	0.744	17.192	246	2.55E-03
2471.36	15.801	0.634	16.336		
617.85	16.202	0.675	16.001		
19.31	17.732	0.833	16.967		

WATER CONTENT %, initial	35	LIQUID LIMIT %	55
WATER CONTENT %, final	33	PLASTIC LIMIT %	32
UNIT WEIGHT, kN/m ³	18.67		

PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)

CONSOLIDATION
SHEET 2 OF 2

FIGURE 44-2



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CONSOLIDATION
SHEET 1 OF 2

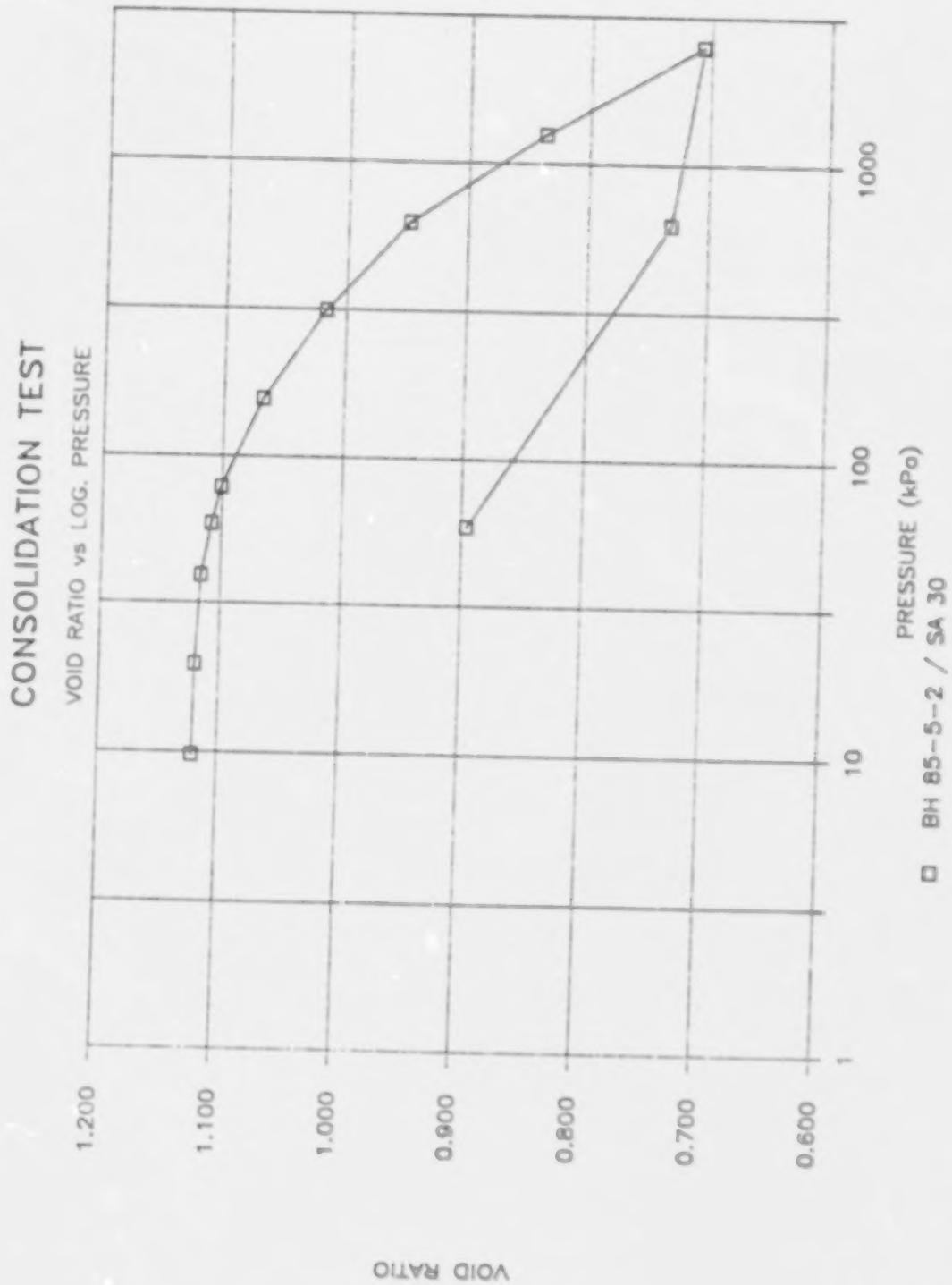
FIGURE 45-1

PROJECT 851-1298 SPECIFIC GRAVITY 2.78 DATE ST. 86-01-27
SAMPLE BH.85-3-2 SA.30 DRY WEIGHT, gm 78.08 DATE FN. 86-02-05
AREA(mm²) 3126.3 SOLIDS HT.mm (2HS) 8.984

Applied Load kPa	Corr. Height mm	Void Ratio	Average Height mm	t ₉₀ sec	Cv cm ² / s t ₉₀
0.00	19.050	1.120	19.050	swelling	
9.78	19.051	1.121	19.050	swelling	
19.55	19.041	1.119	19.046	swelling	
39.11	19.008	1.116	19.024	180	4.26E-03
58.66	18.939	1.108	18.973	360	2.12E-03
78.22	18.871	1.101	18.905	540	1.20E-03
156.44	18.572	1.067	18.721	900	8.26E-04
312.88	18.120	1.017	18.346	940	8.50E-04
625.76	17.500	0.948	17.810	174	7.87E-03
1251.52	16.500	0.837	17.000	1500	4.04E-04
2503.04	15.331	0.706	15.915		
625.76	15.549	0.731	15.440		
58.66	17.031	0.896	16.298		

WATER CONTENT %, initial 42 LIQUID LIMIT % 41
WATER CONTENT %, final 37 PLASTIC LIMIT % 23
UNIT WEIGHT, kN/m³ 18.24

PROJECT 851-1298 (GLAL PROJECT # 85-GT-4)



May, 1986

851-1298

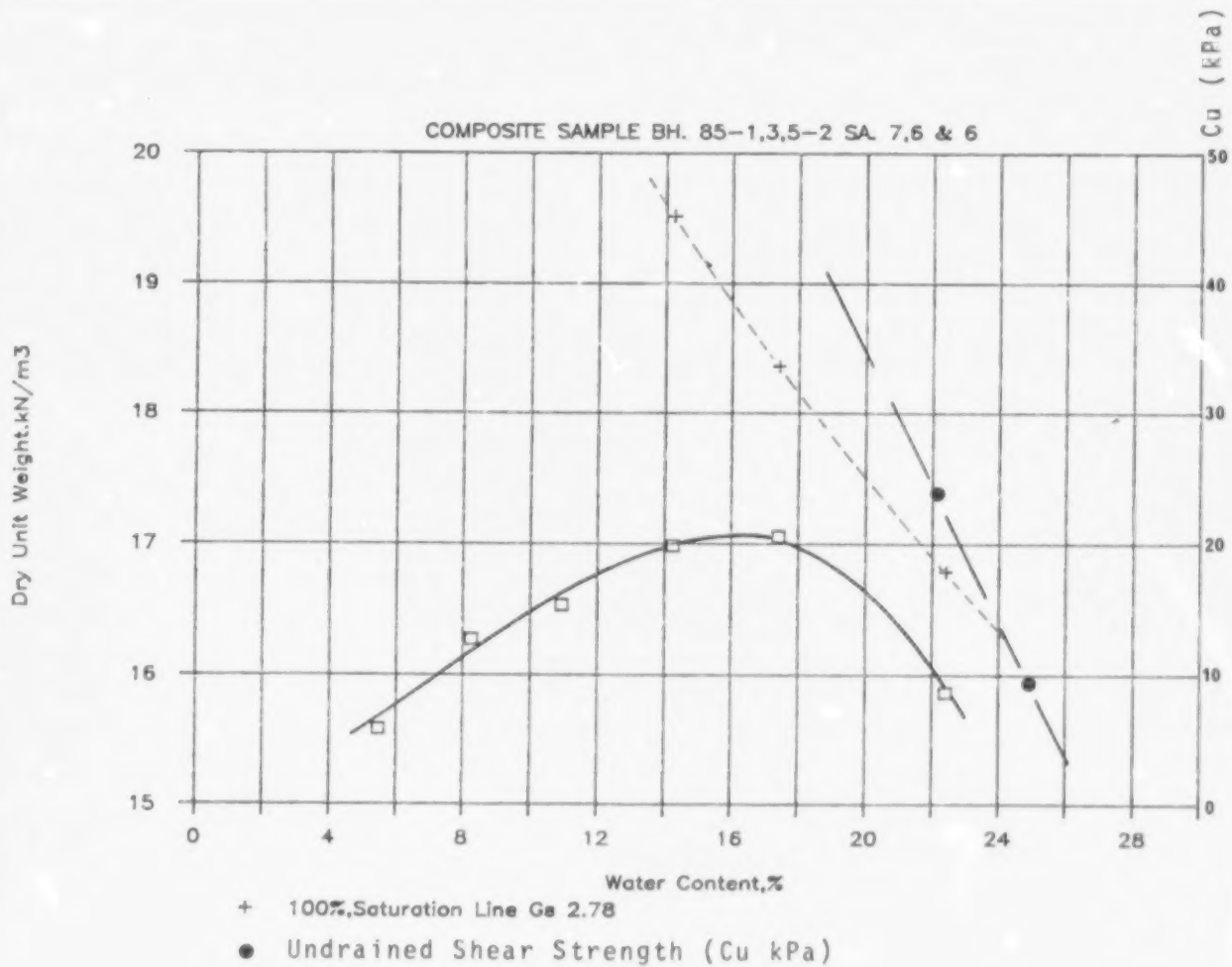
LABORATORY COMPACTION TEST RESULTS

FIGURES 46 and 47

LABORATORY COMPACTION TEST RESULTS

SHEET 1 OF 1

FIGURE 46

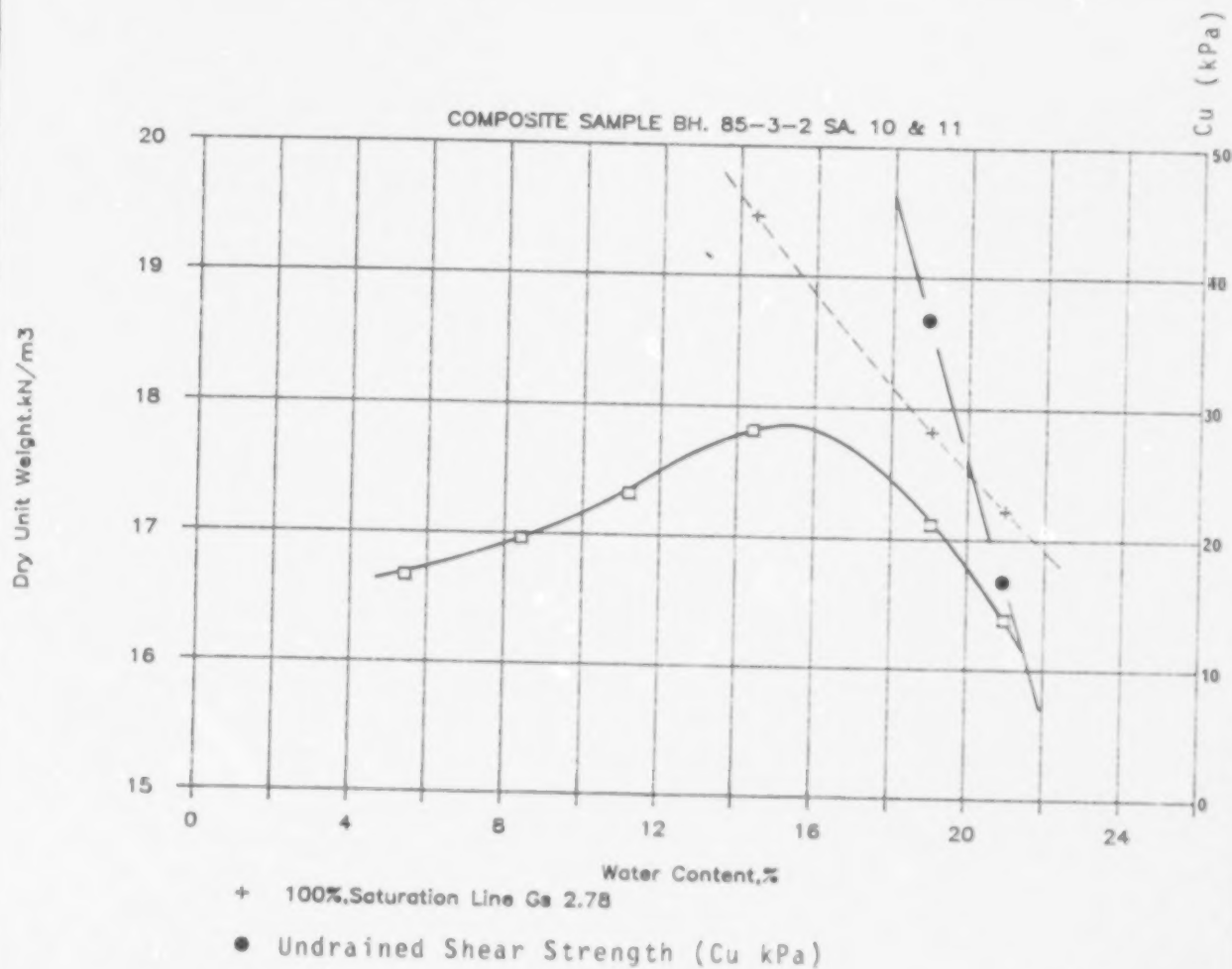


Dry Unit Weight, kN/m³	17.12	Passing Sieve	no. 4
Optimum Water Content, %	16.4	Tested By	MM
Natural Water Content, %		Date of Test	85/04/28
Project Number	851-1298	Sample Number	1/7-3/6-5/6 composite
Material Type	UPPER	Data By	FAR

LABORATORY COMPACTION TEST RESULTS

SHEET 1 OF 1

FIGURE 47



Dry Unit Weight, kN/m³	17.85	Passing Sieve	no. 4
Optimum Water Content, %	15.6	Tested By	HW
Natural Water Content, %		Date of Test	85/04/28
Project Number	851-1298	Sample Number	85-3-2 10 & 11
Material Type	Till	Data By	FAR

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May, 1986

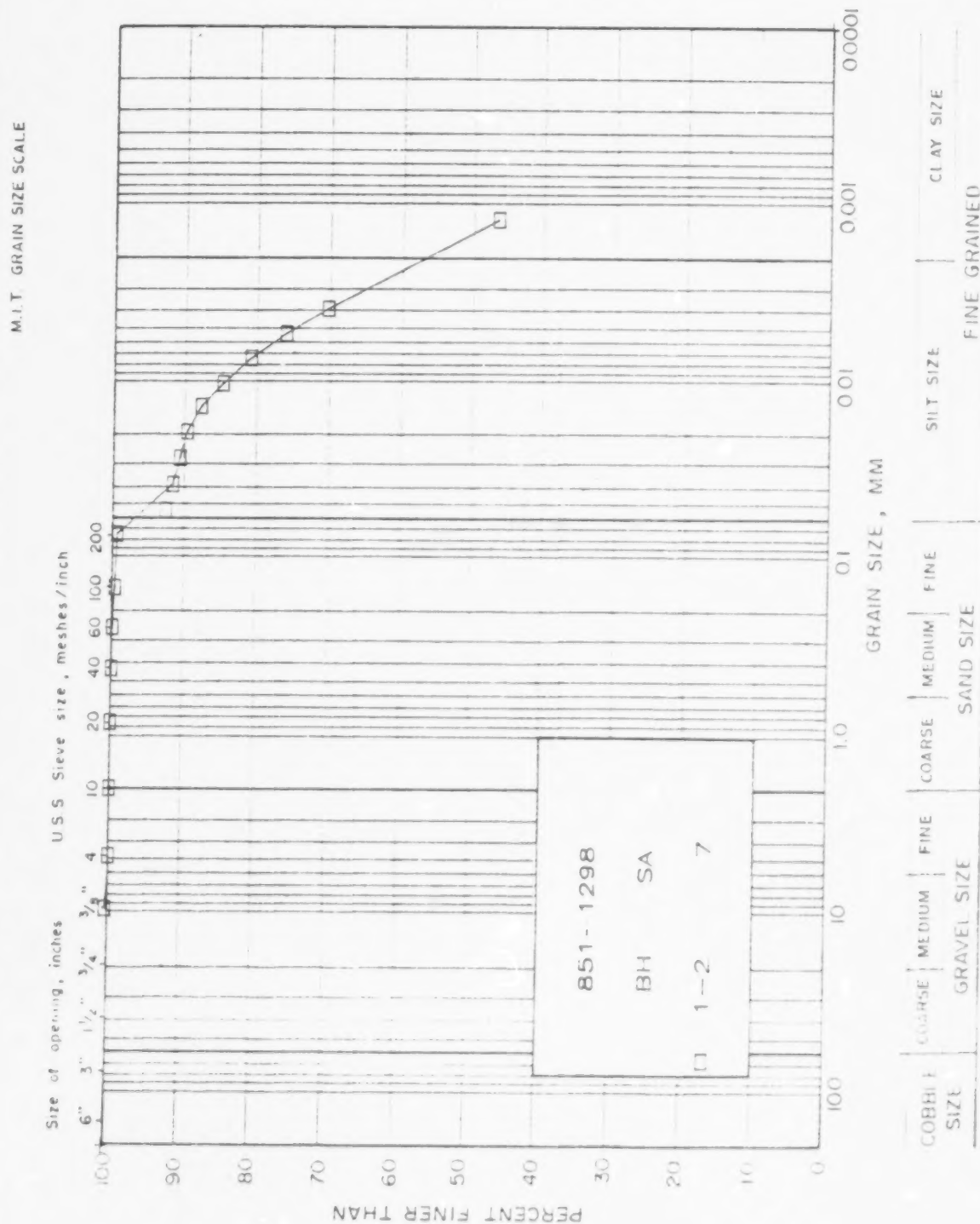
851-1298

GRAIN SIZE DISTRIBUTION

FIGURES 48 to 73

GRAIN SIZE DISTRIBUTION

FIGURE 48

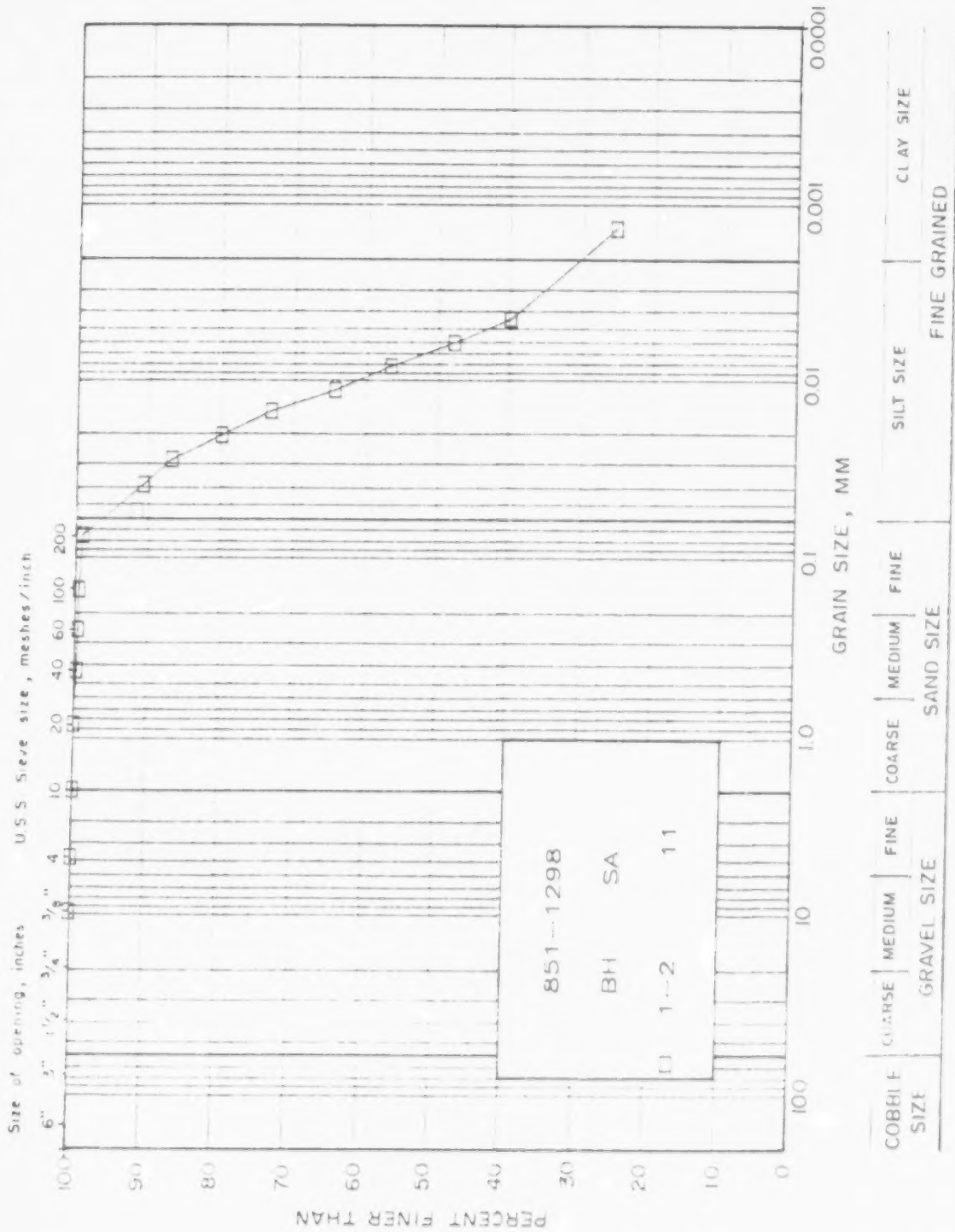


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GRAIN SIZE DISTRIBUTION

FIGURE 49

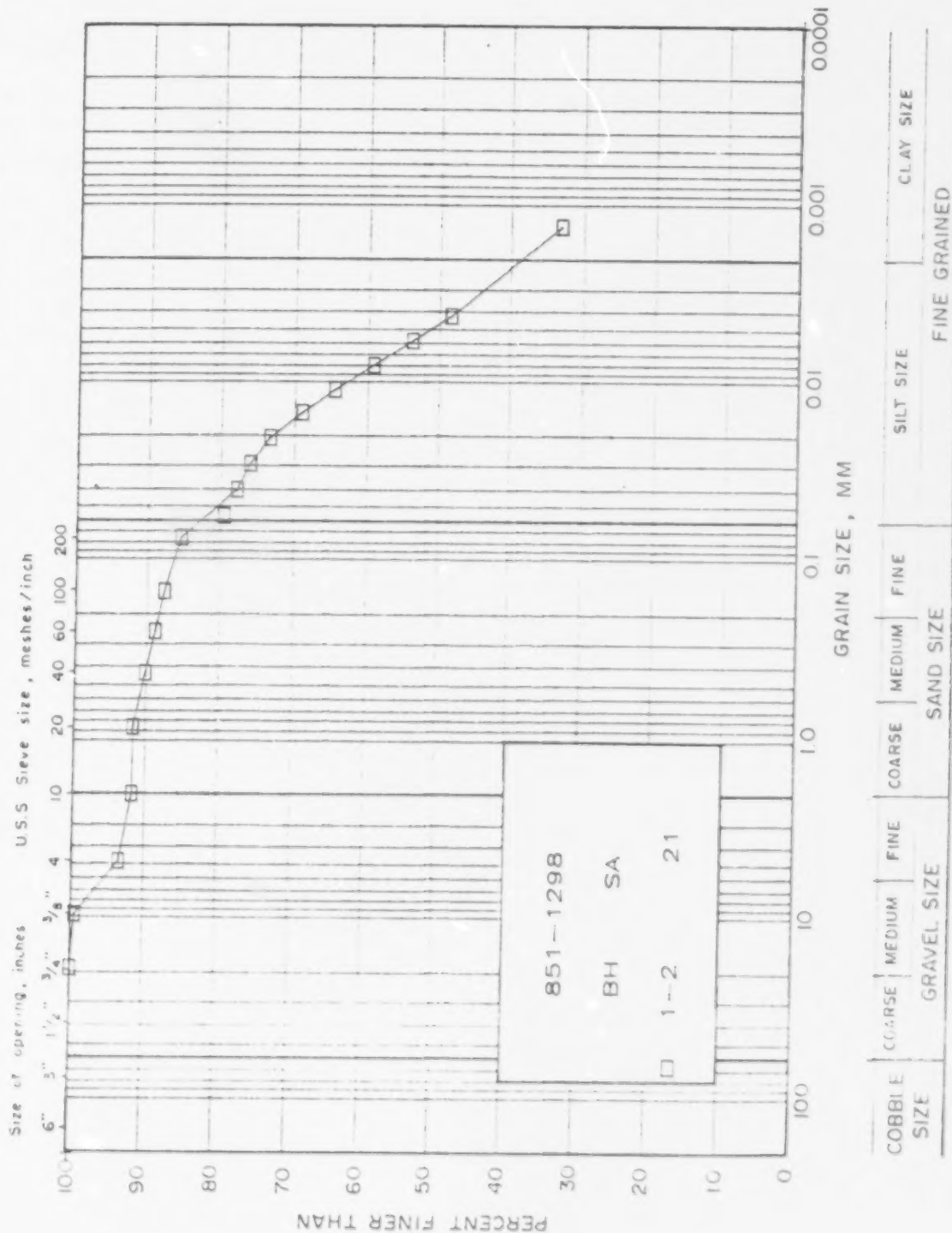
M I T GRAIN SIZE SCALE



GRAIN SIZE DISTRIBUTION

FIGURE 50

M.I.T. GRAIN SIZE SCALE

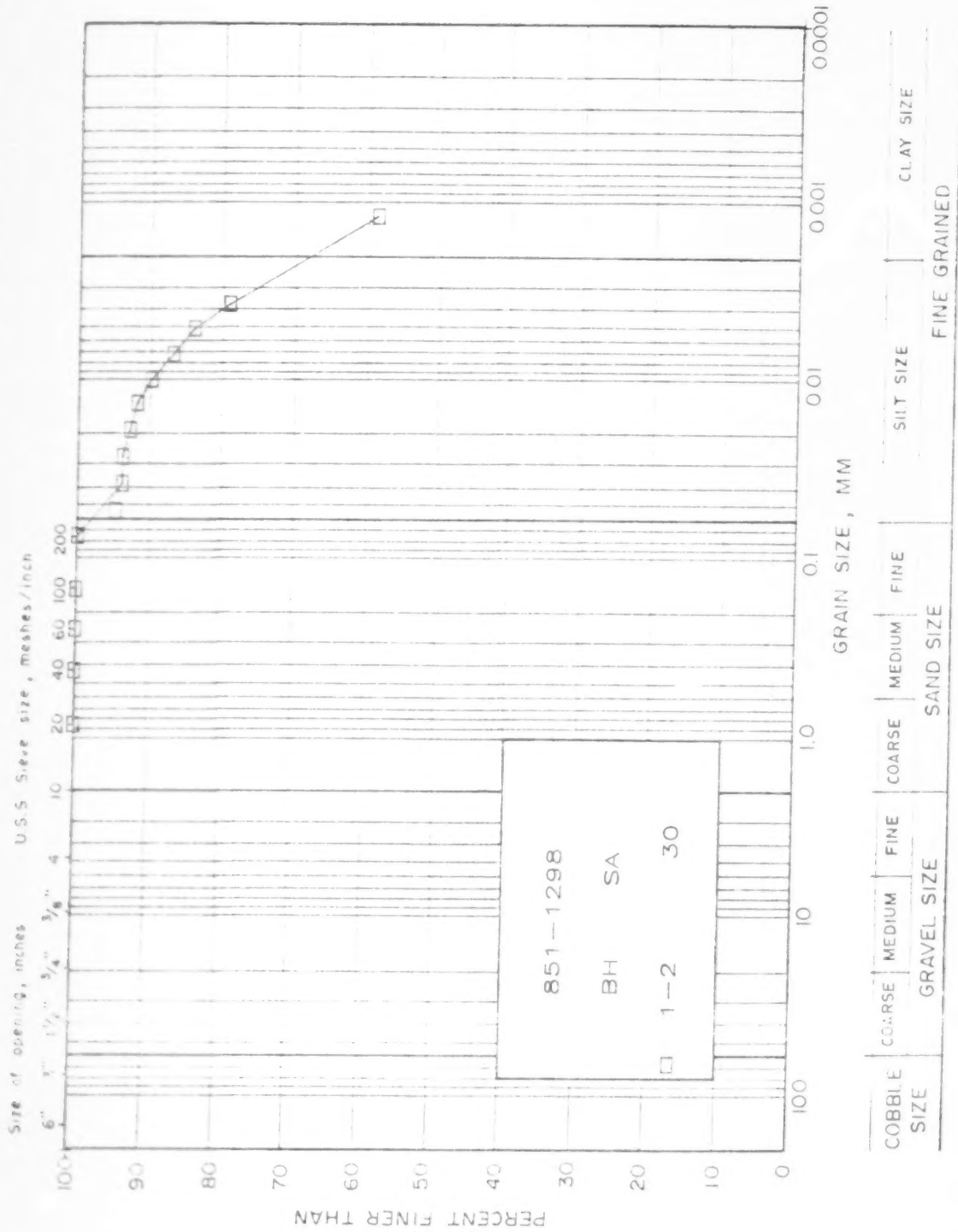


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GRAIN SIZE DISTRIBUTION

FIGURE 51

M.I.T. GRAIN SIZE SCALE

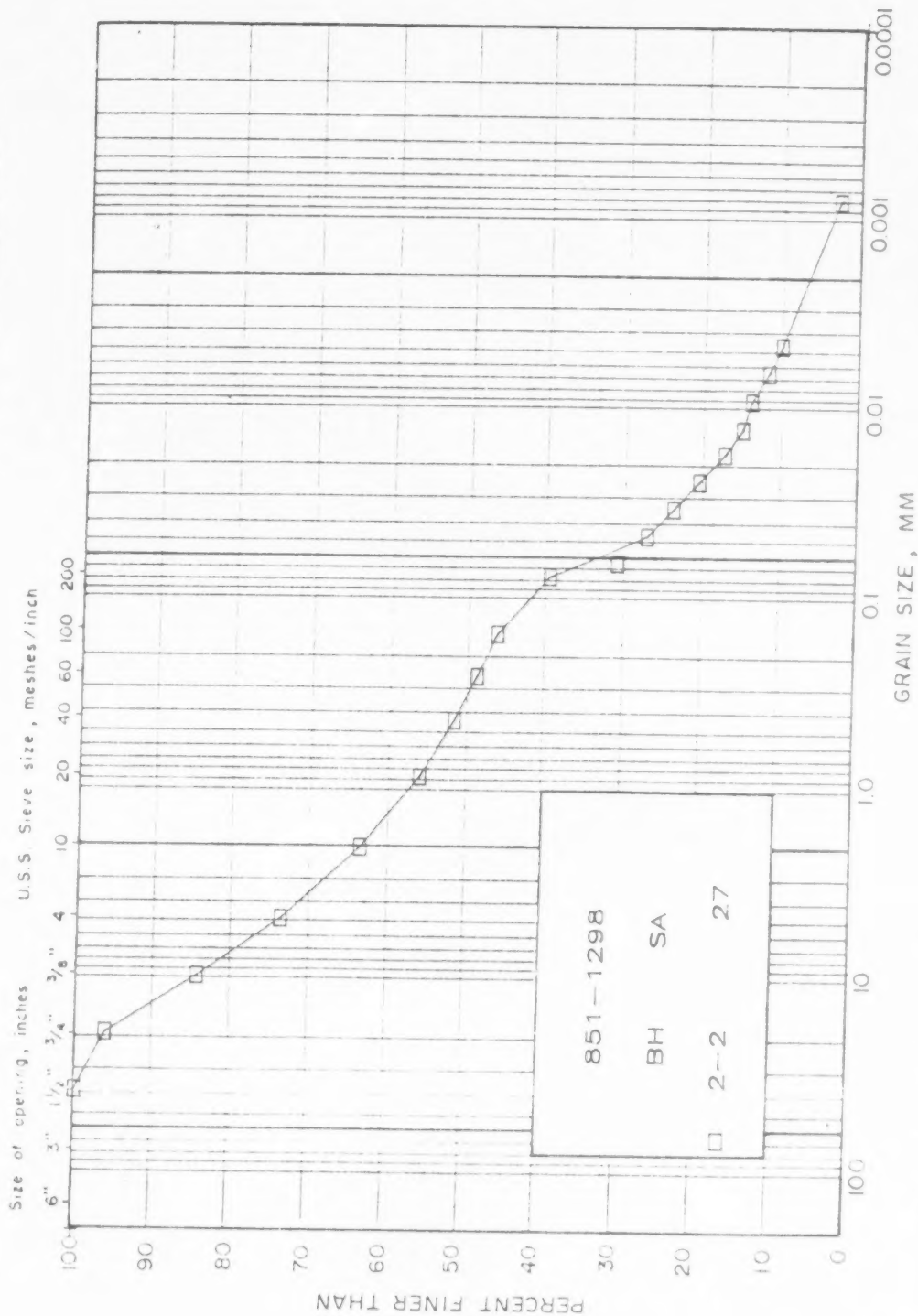


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GRAIN SIZE DISTRIBUTION

FIGURE 52

M.I.T. GRAIN SIZE SCALE



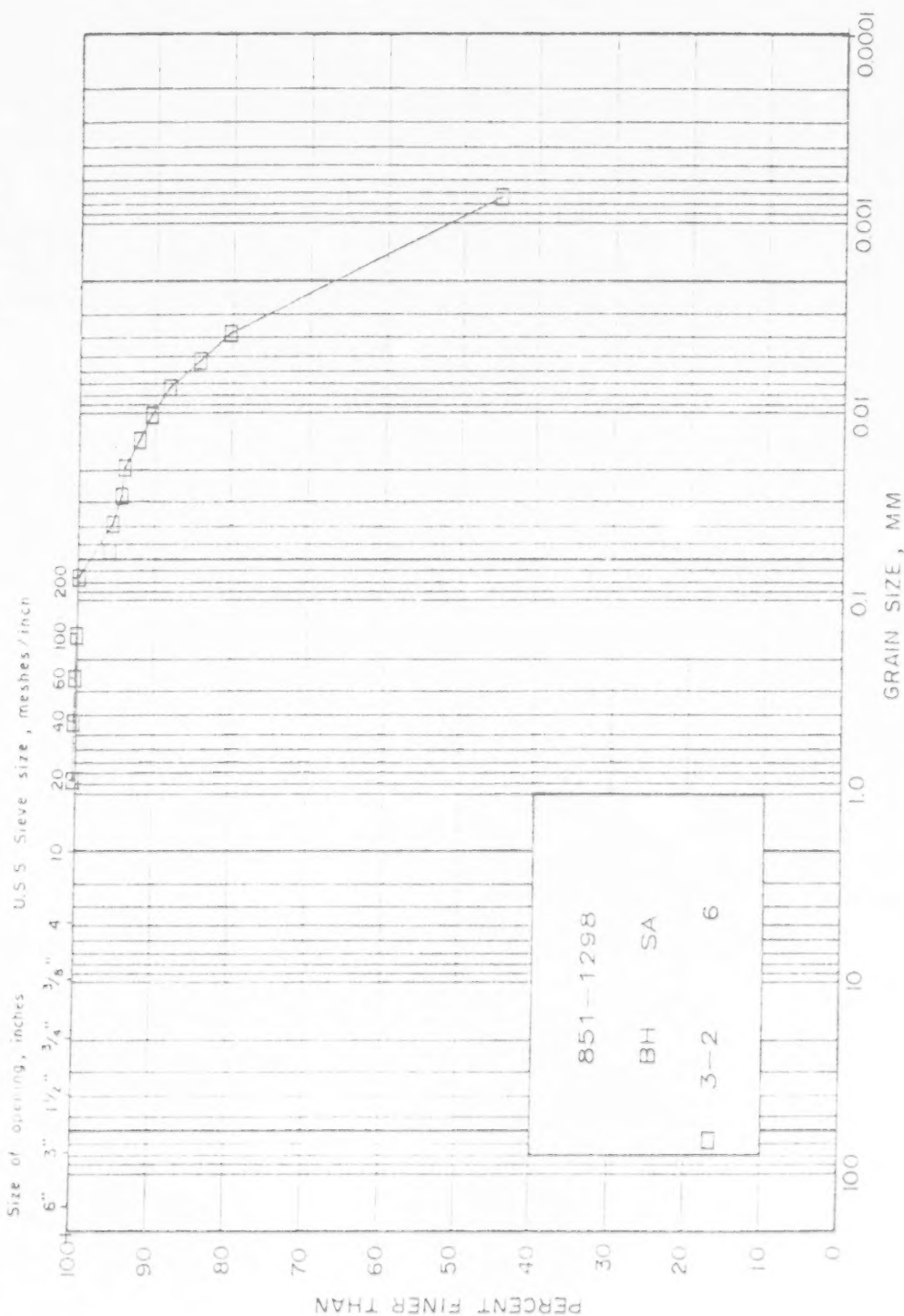
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

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GRAIN SIZE DISTRIBUTION

FIGURE 53

M.I.T. GRAIN SIZE SCALE

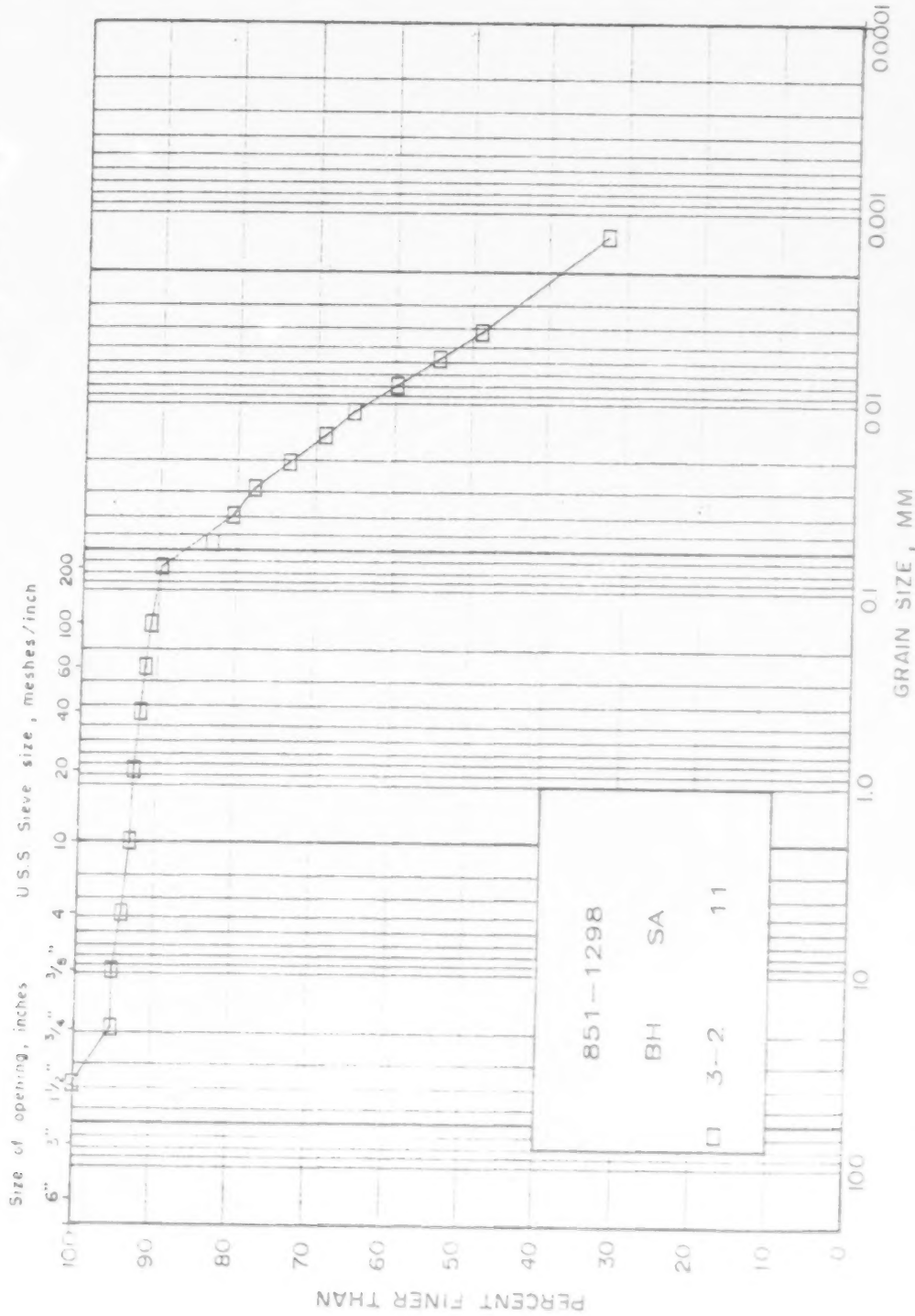


PROJECT No. _____

GRAIN SIZE DISTRIBUTION

FIGURE 54

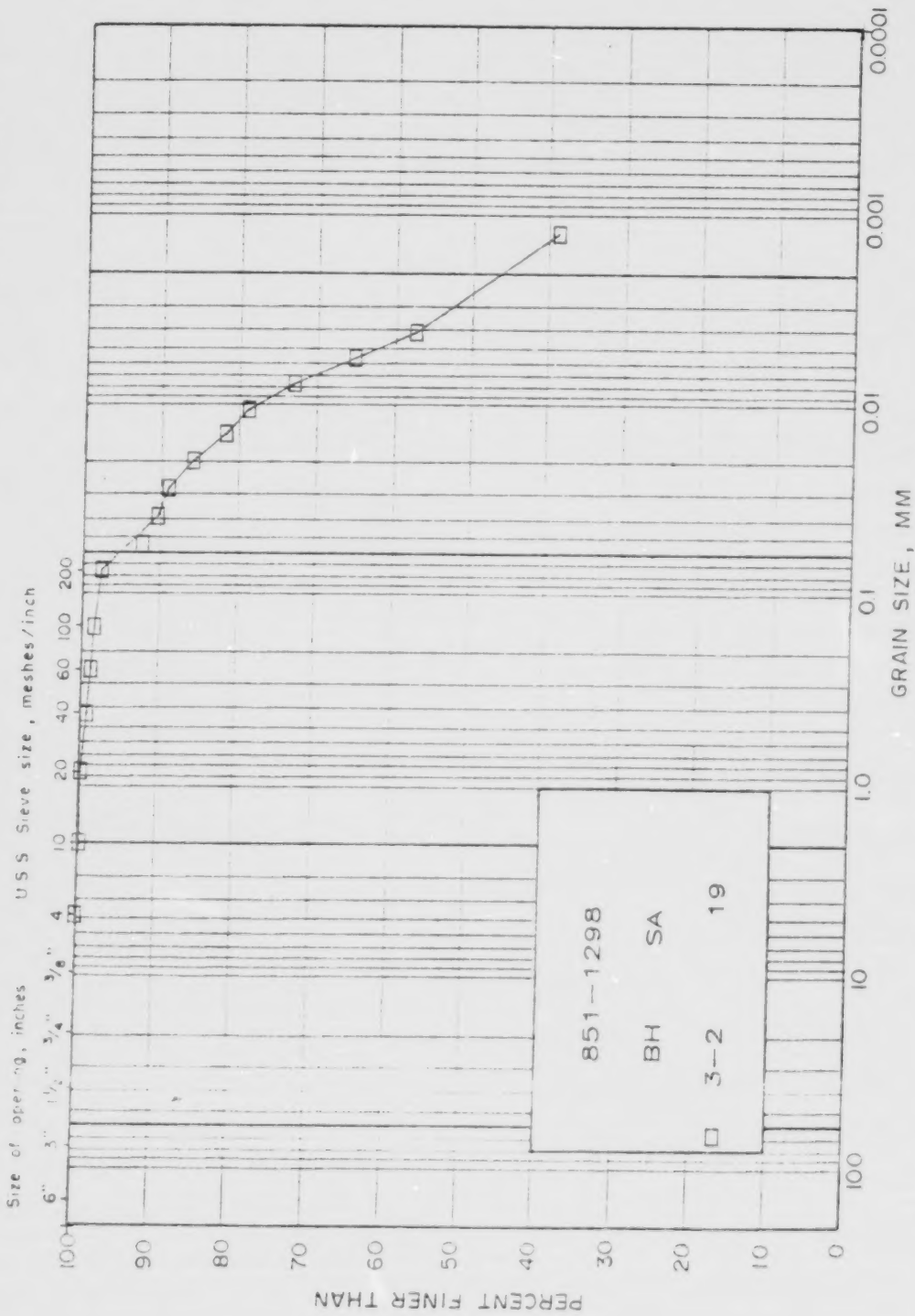
M.I.T. GRAIN SIZE SCALE



GRAIN SIZE DISTRIBUTION

FIGURE 55

M.I.T. GRAIN SIZE SCALE



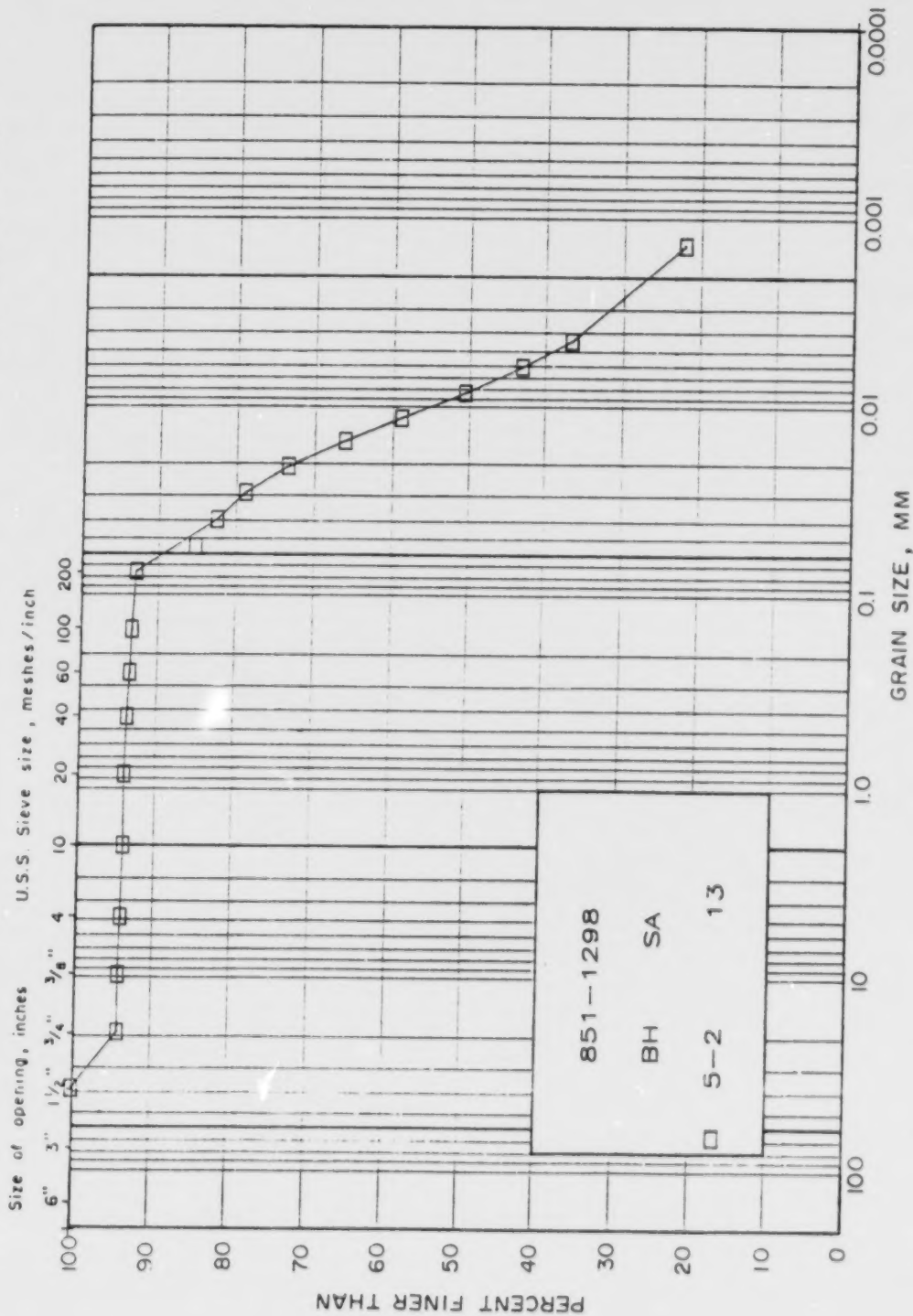
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

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GRAIN SIZE DISTRIBUTION

FIGURE 56

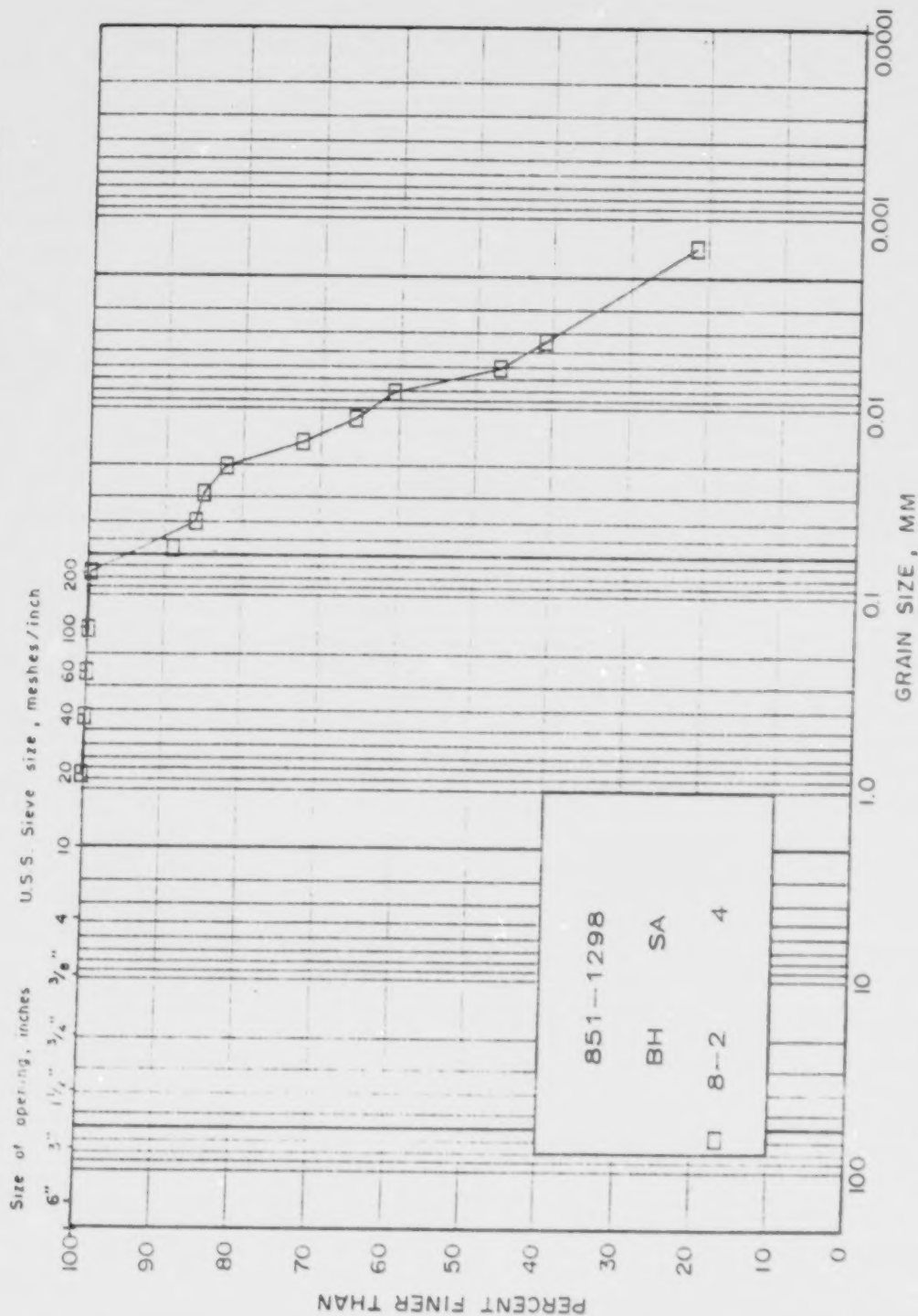
M.I.T. GRAIN SIZE SCALE



GRAIN SIZE DISTRIBUTION

FIGURE 57

M.I.T. GRAIN SIZE SCALE



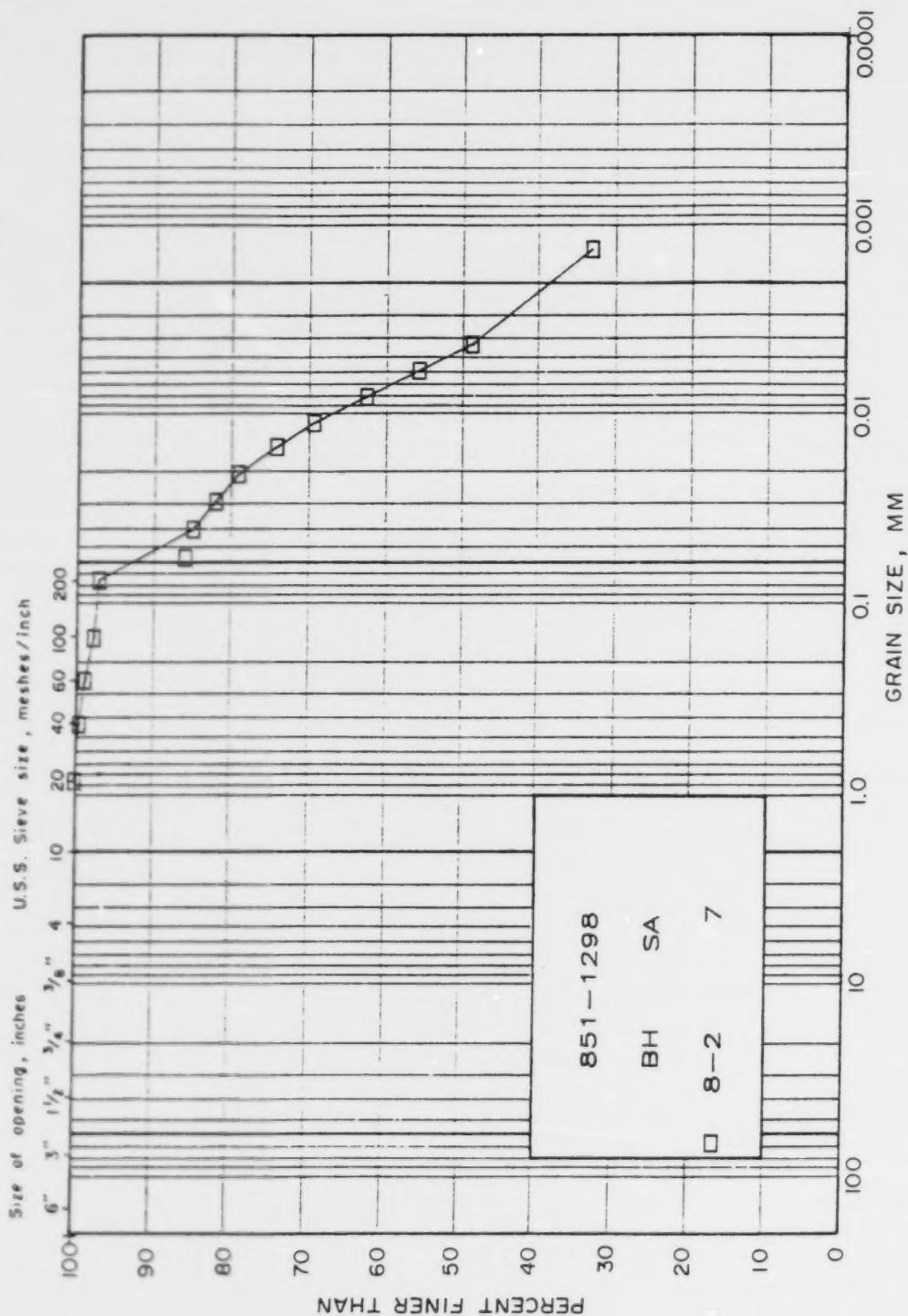
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

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GRAIN SIZE DISTRIBUTION

FIGURE 58

M.I.T. GRAIN SIZE SCALE



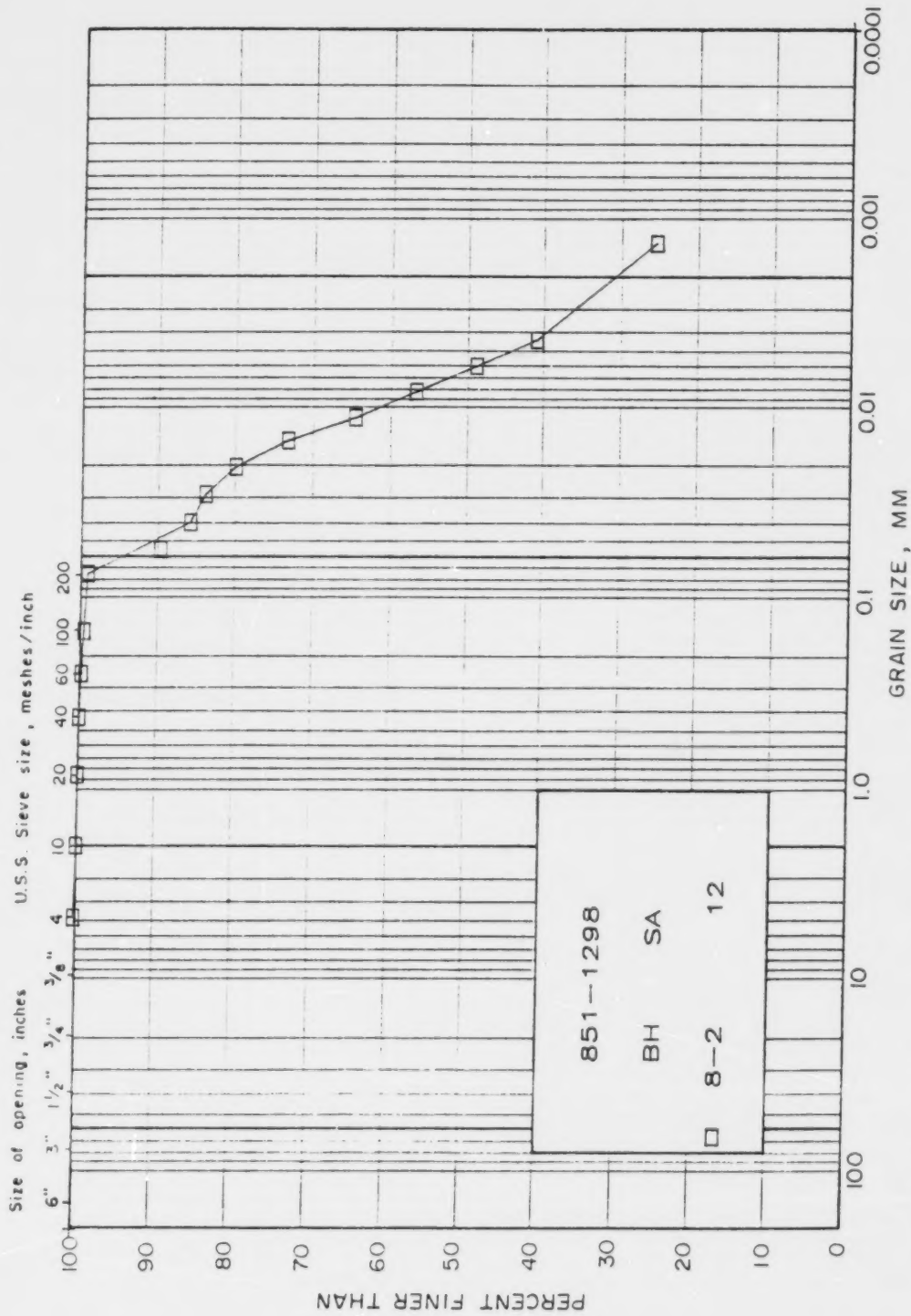
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE 59

M.I.T. GRAIN SIZE SCALE



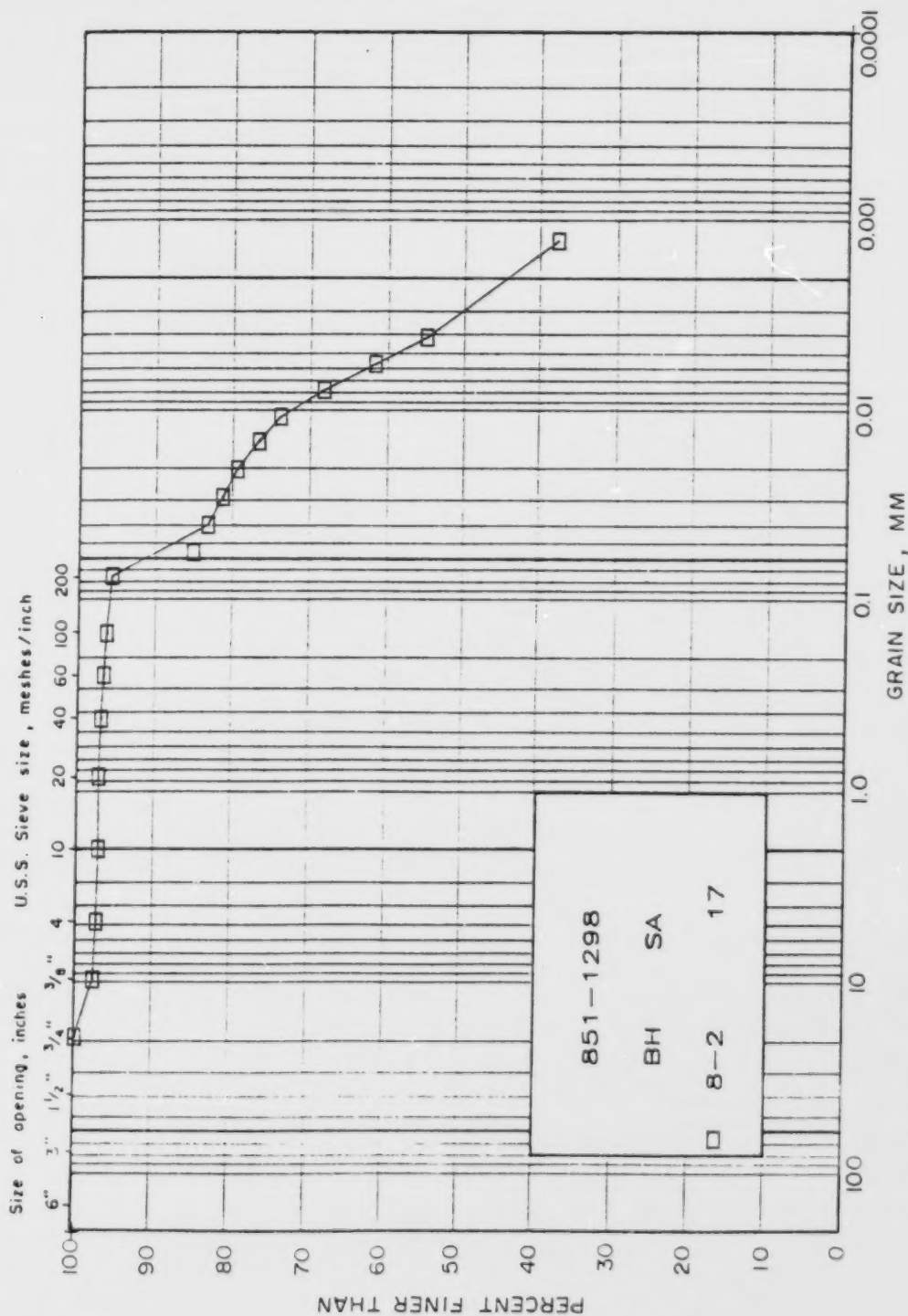
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

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GRAIN SIZE DISTRIBUTION

FIGURE 60

M.I.T. GRAIN SIZE SCALE



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BH SA

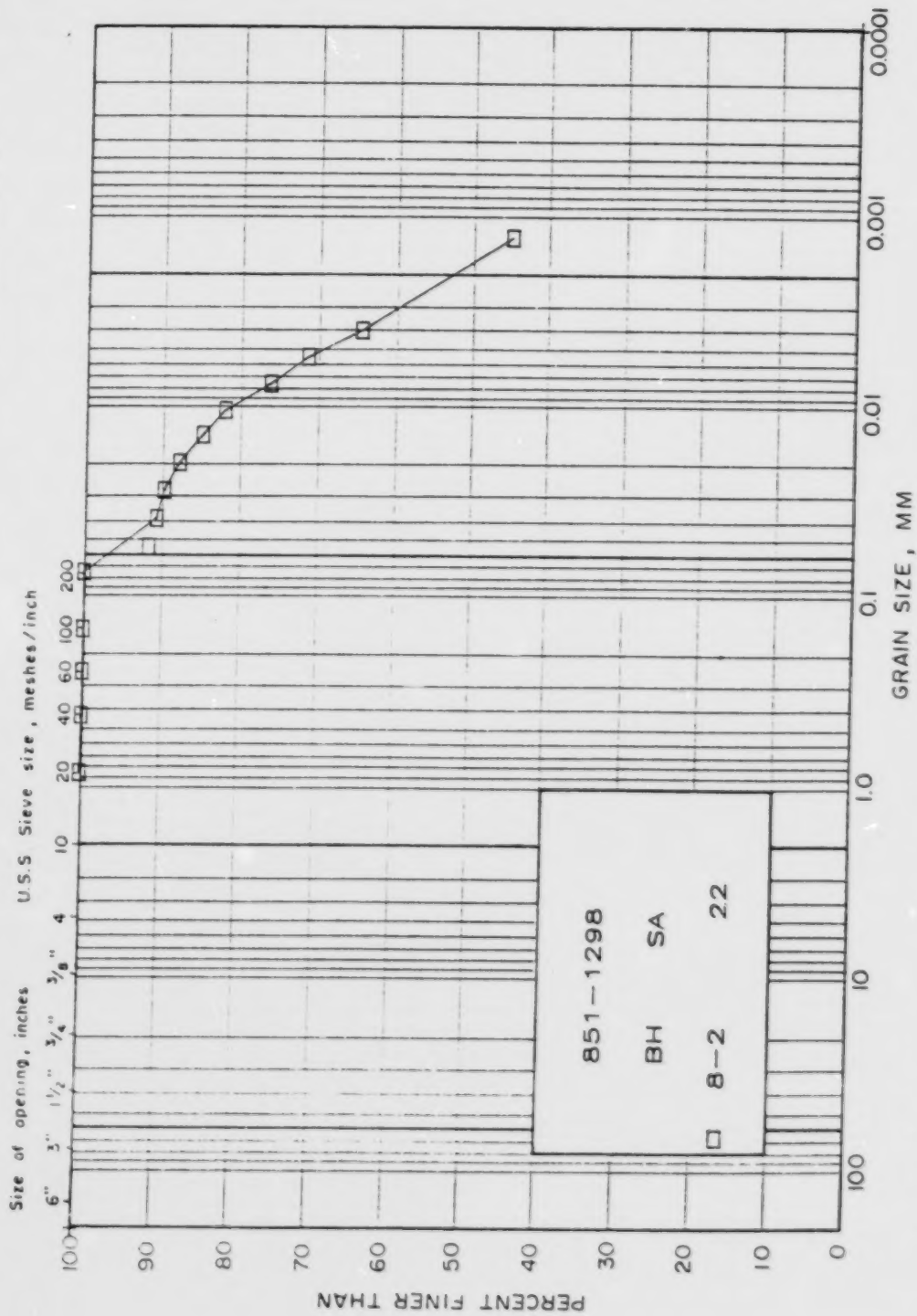
8-2 17

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GRAIN SIZE DISTRIBUTION

FIGURE 61

M.I.T. GRAIN SIZE SCALE



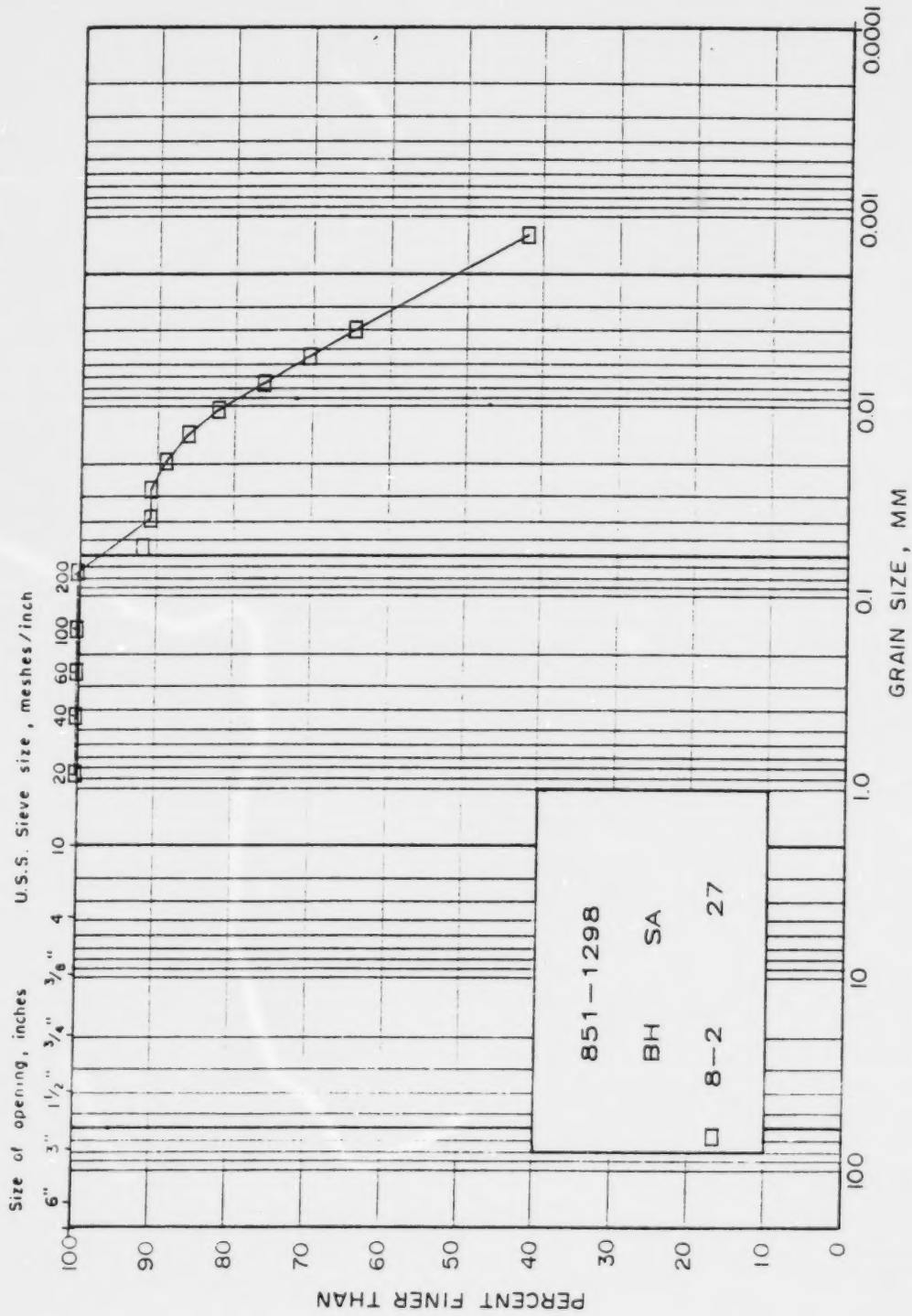
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE 62

M.I.T. GRAIN SIZE SCALE



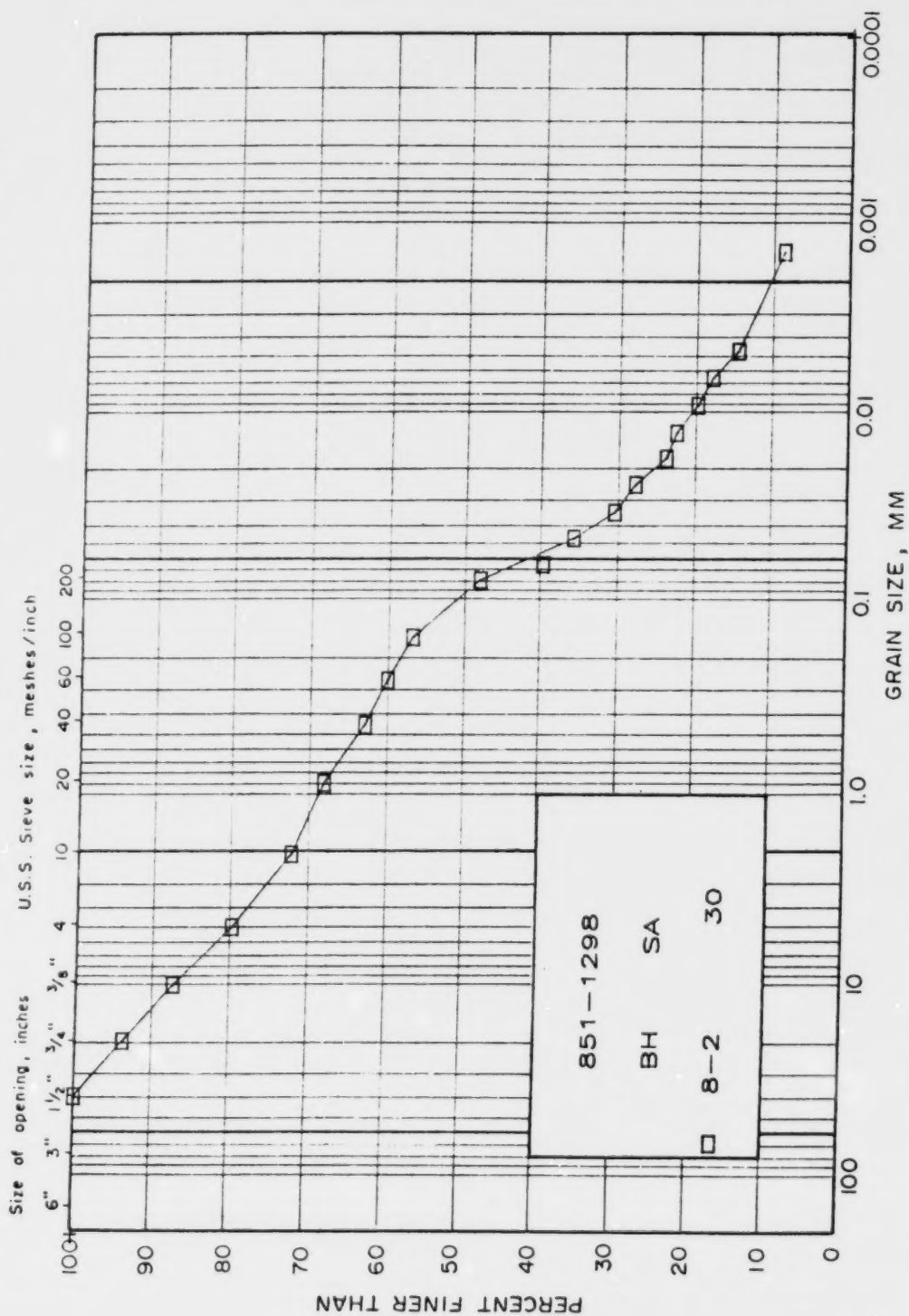
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE 63

M.I.T. GRAIN SIZE SCALE

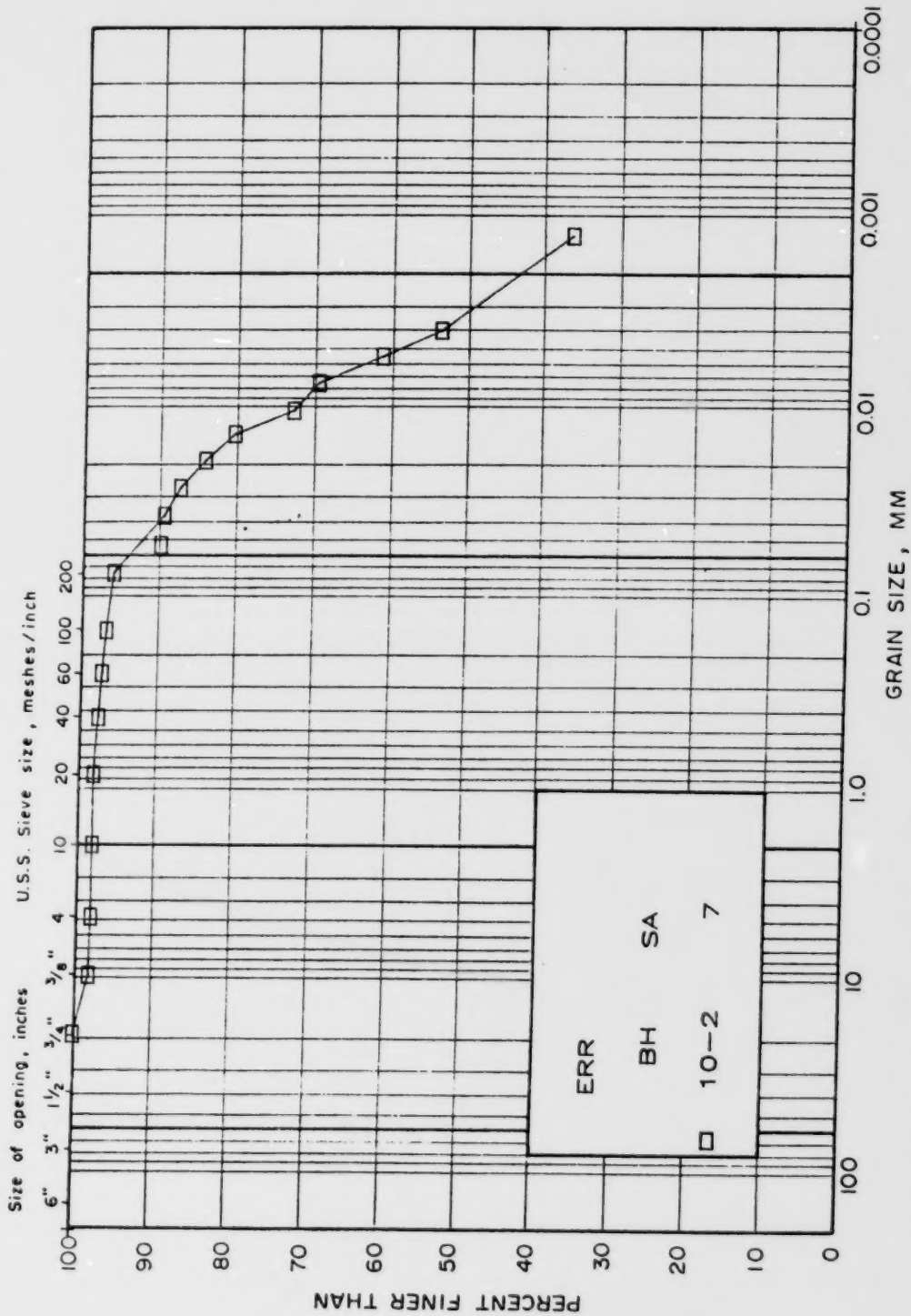


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GRAIN SIZE DISTRIBUTION

FIGURE 64

M.I.T. GRAIN SIZE SCALE



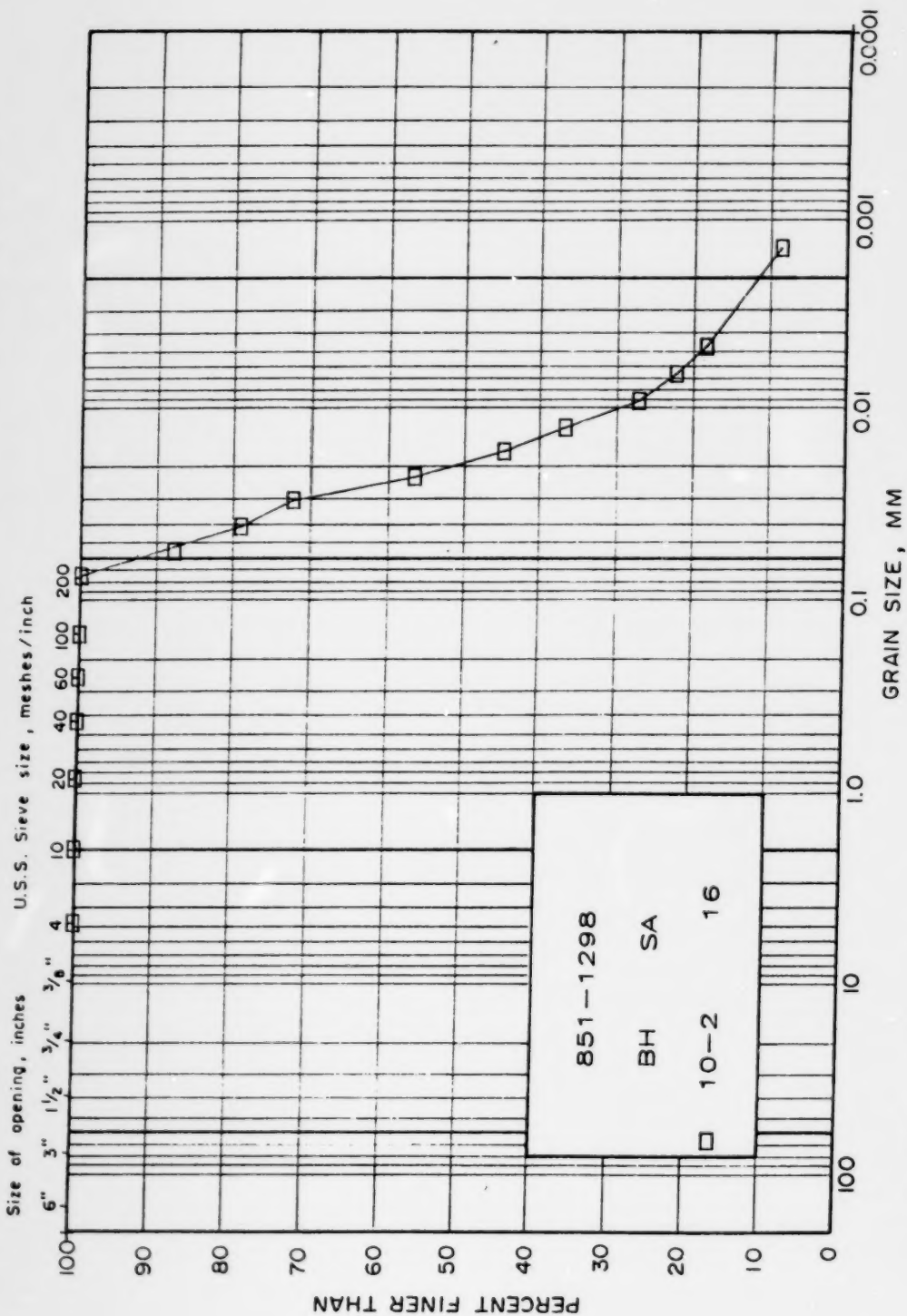
COBBLE SIZE	GRAVEL SIZE		SAND SIZE			SILT SIZE		CLAY SIZE	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	FINE GRAINED	CLAY SIZE

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE 65

M.I.T. GRAIN SIZE SCALE



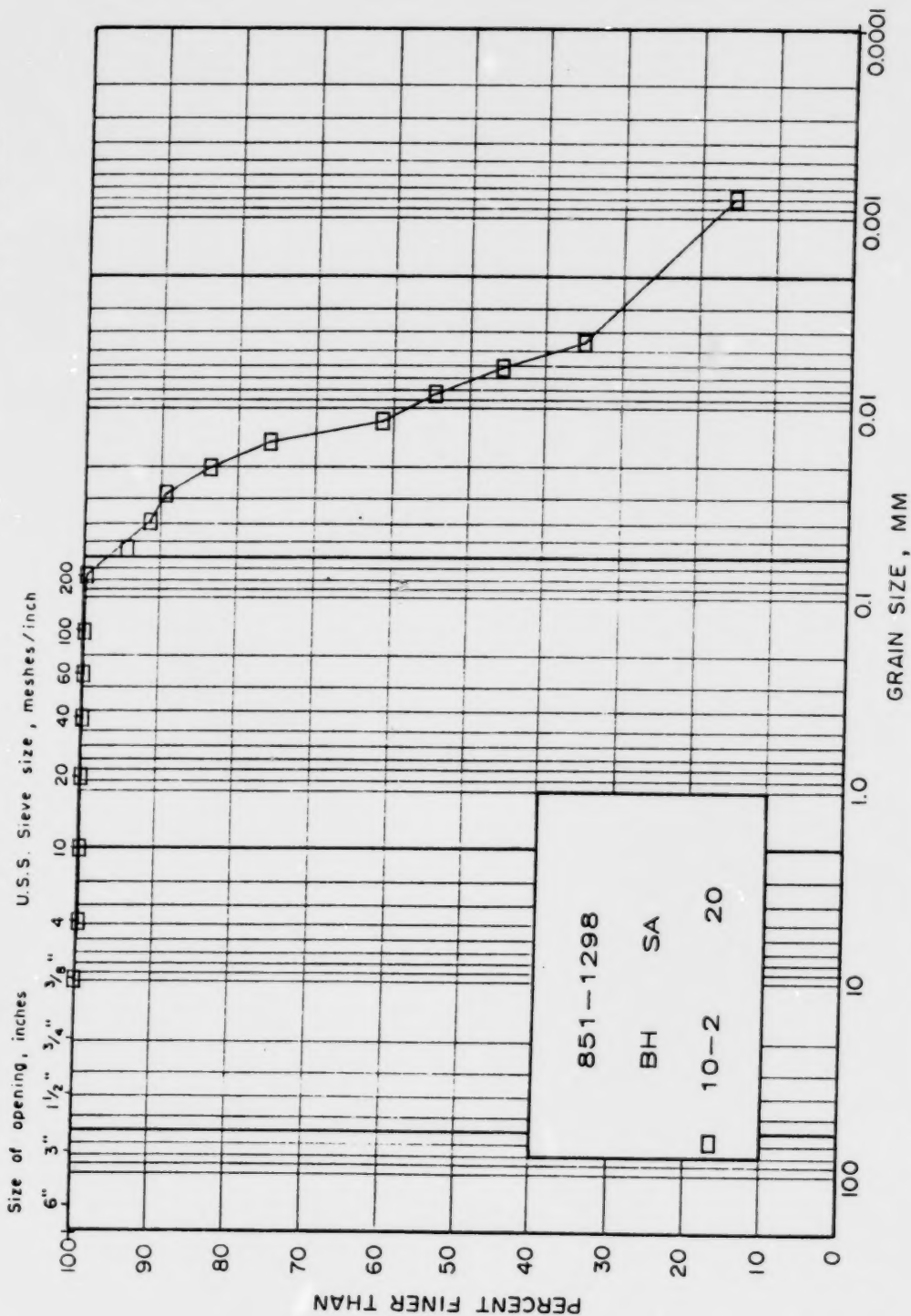
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

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GRAIN SIZE DISTRIBUTION

FIGURE 66

M.I.T. GRAIN SIZE SCALE

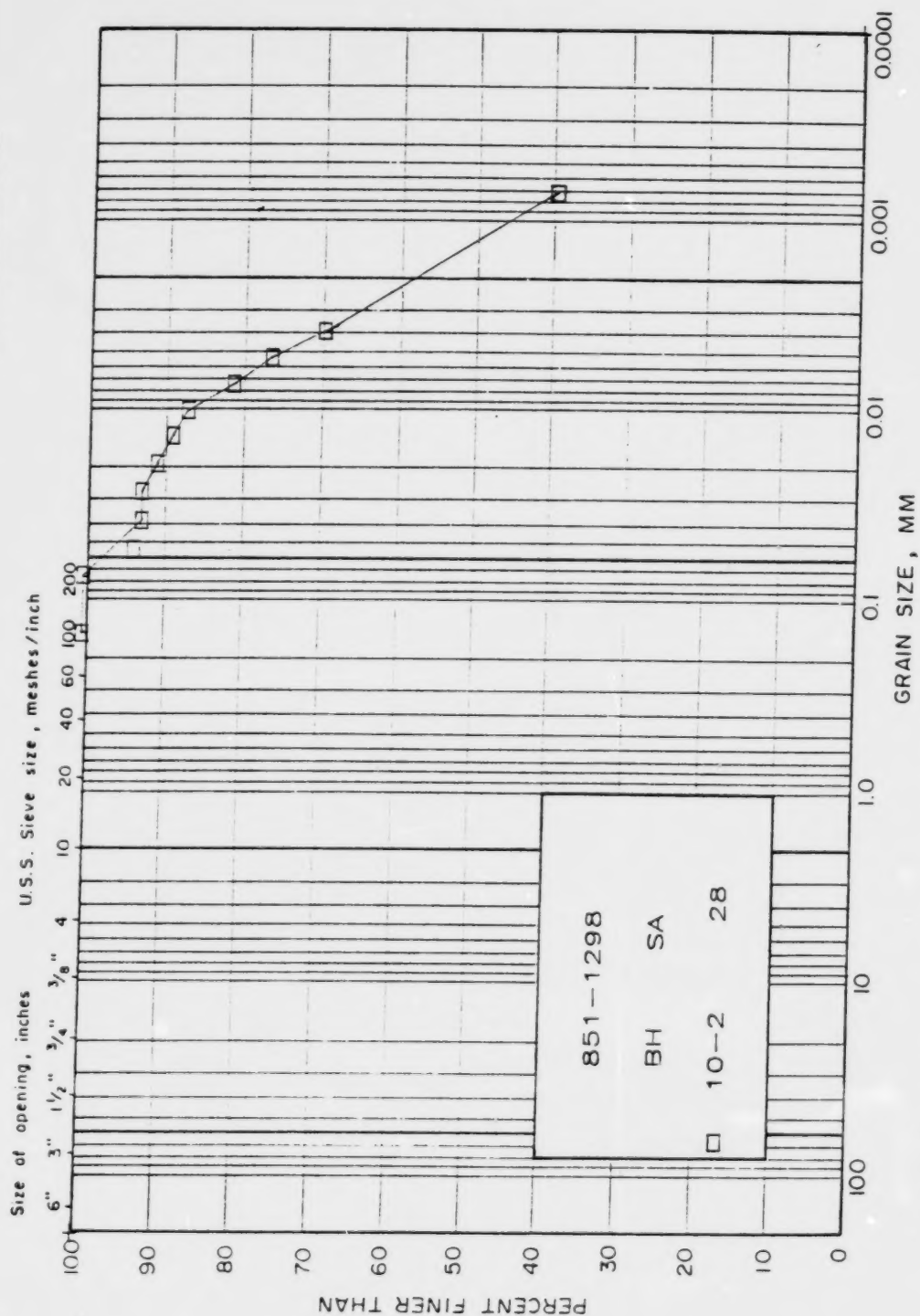


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GRAIN SIZE DISTRIBUTION

FIGURE 67

M.I.T. GRAIN SIZE SCALE



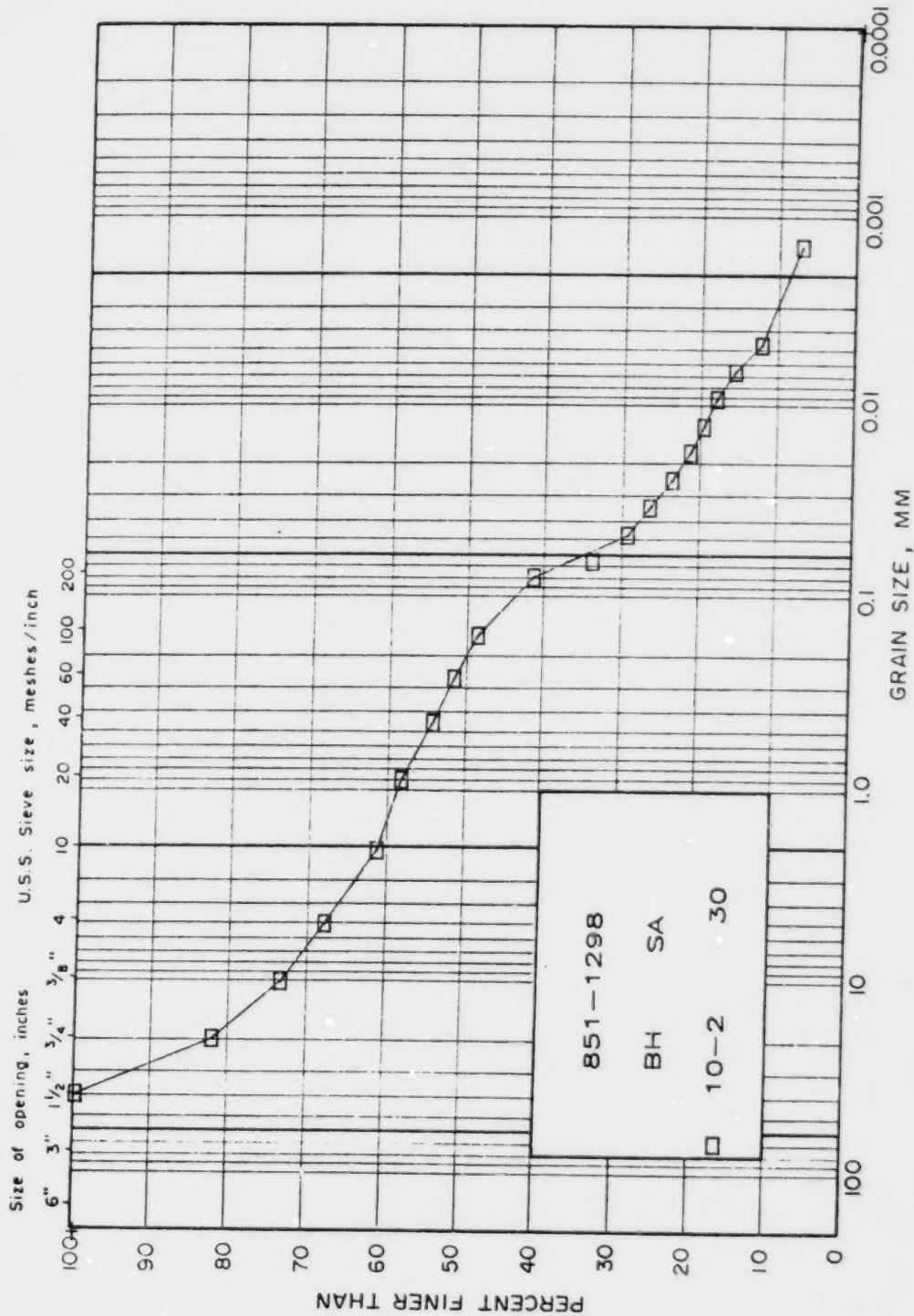
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE 68

M.I.T. GRAIN SIZE SCALE



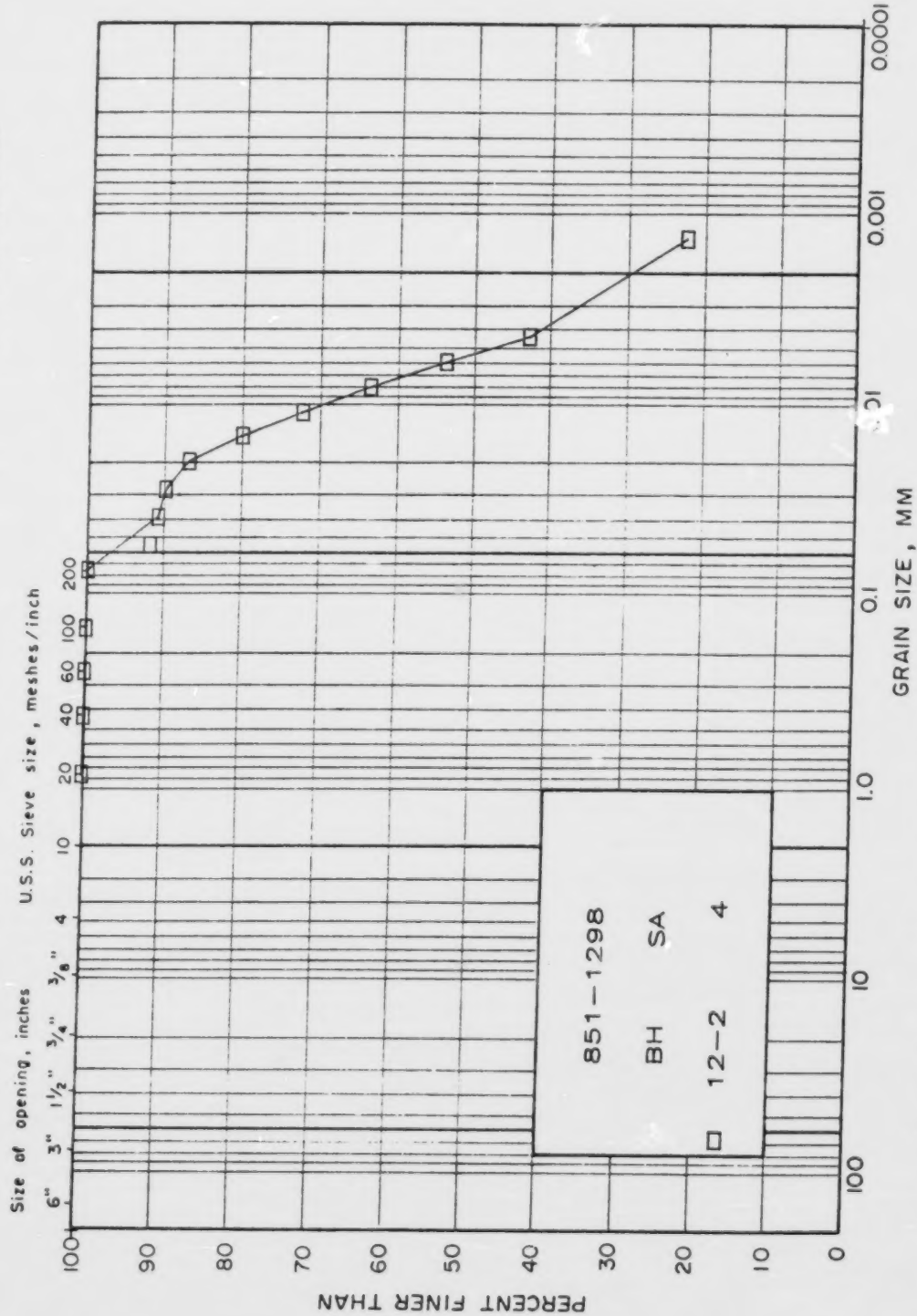
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE 69

M.I.T. GRAIN SIZE SCALE



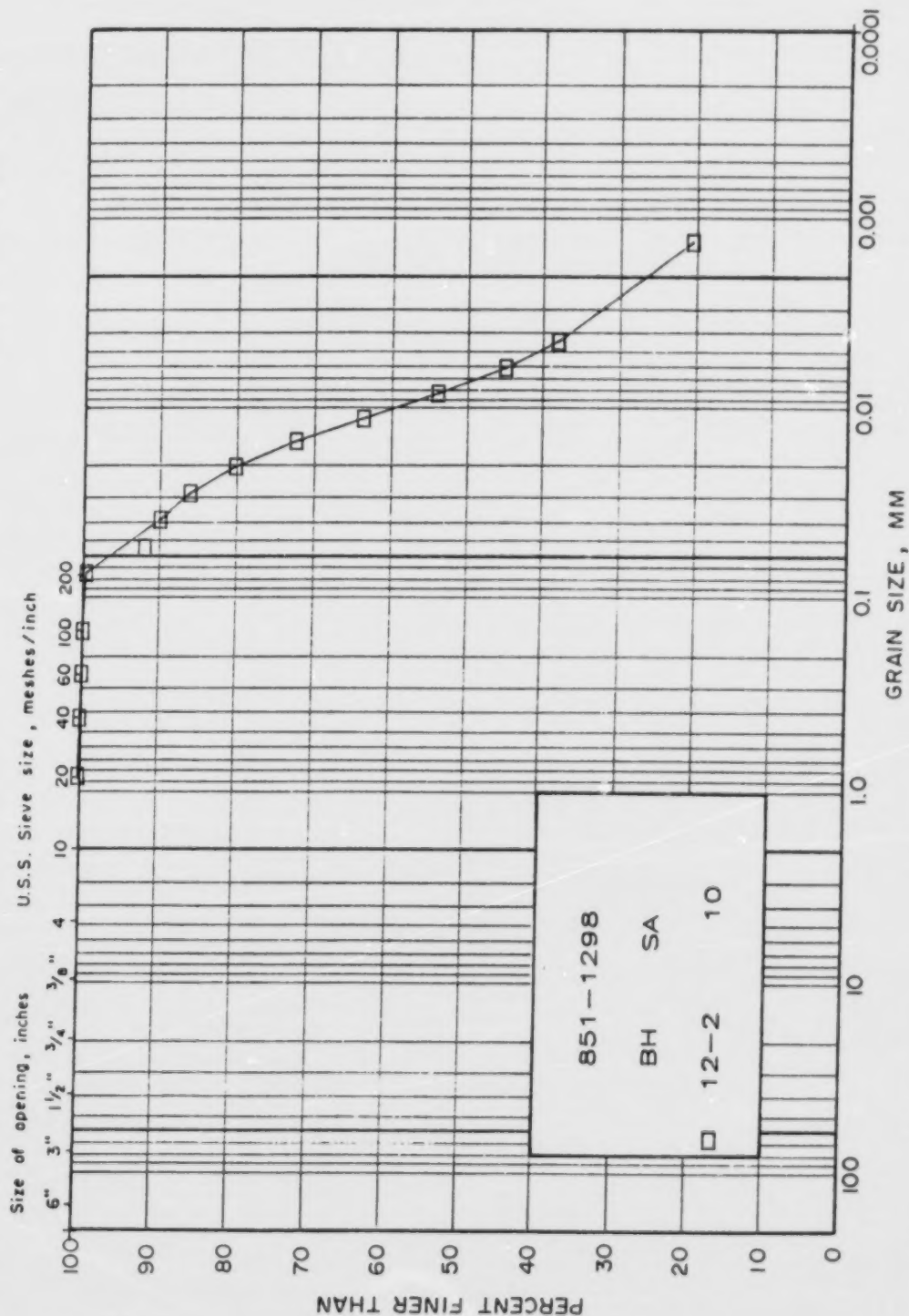
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			FINE GRAINED	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

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GRAIN SIZE DISTRIBUTION

FIGURE 70

M.I.T. GRAIN SIZE SCALE

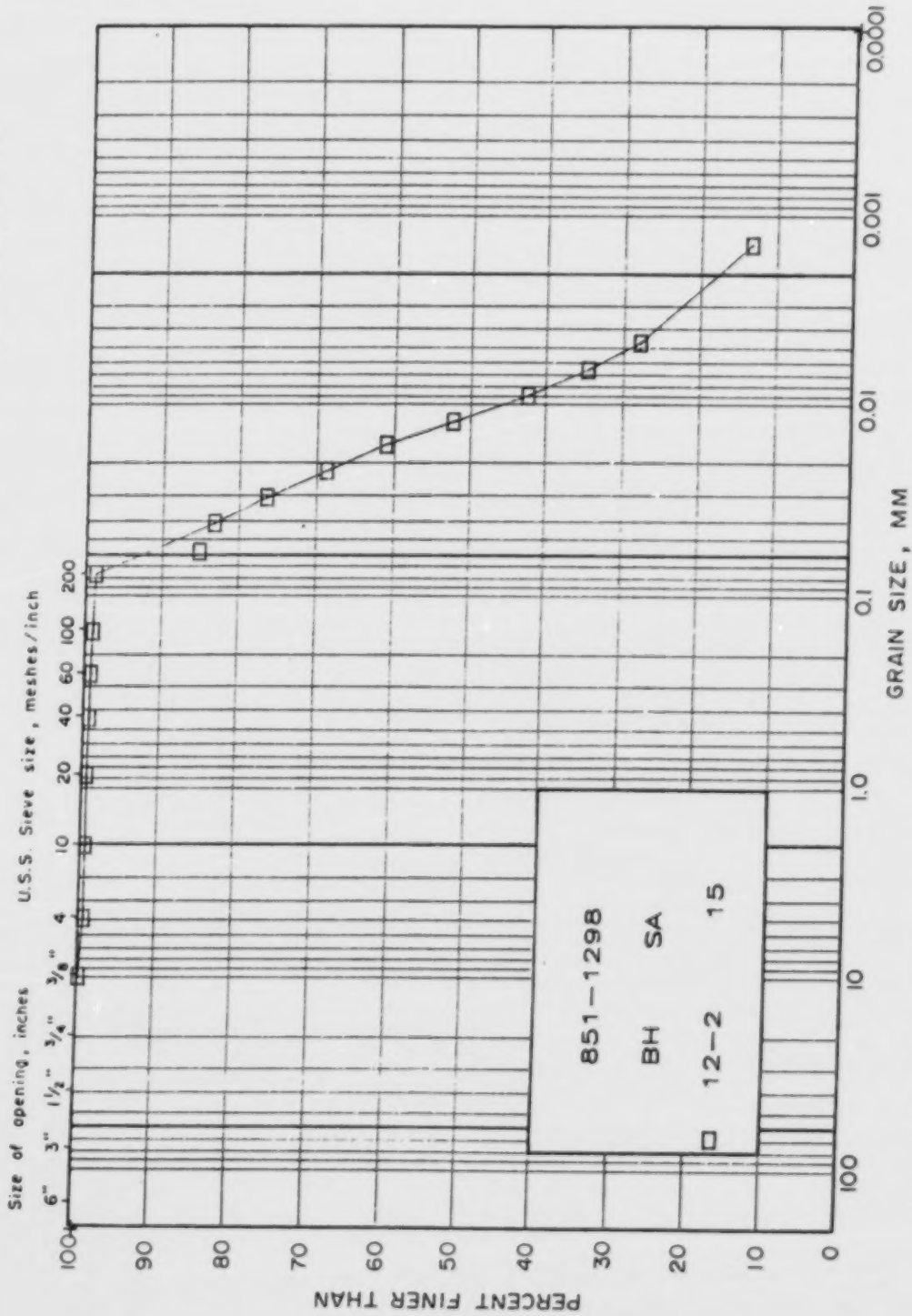


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GRAIN SIZE DISTRIBUTION

FIGURE 71

M.I.T. GRAIN SIZE SCALE

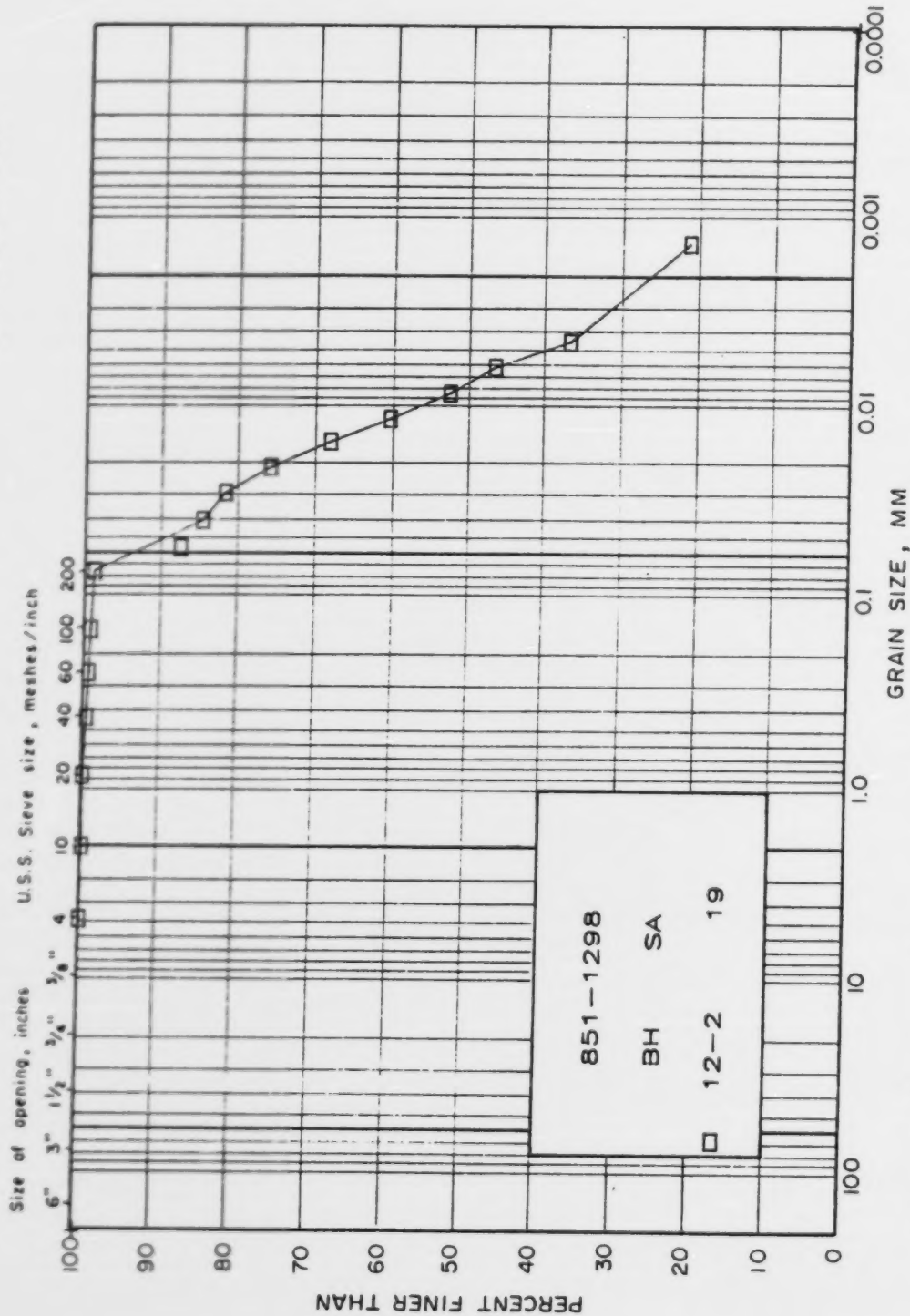


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GRAIN SIZE DISTRIBUTION

FIGURE 72

M.I.T. GRAIN SIZE SCALE



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BH SA

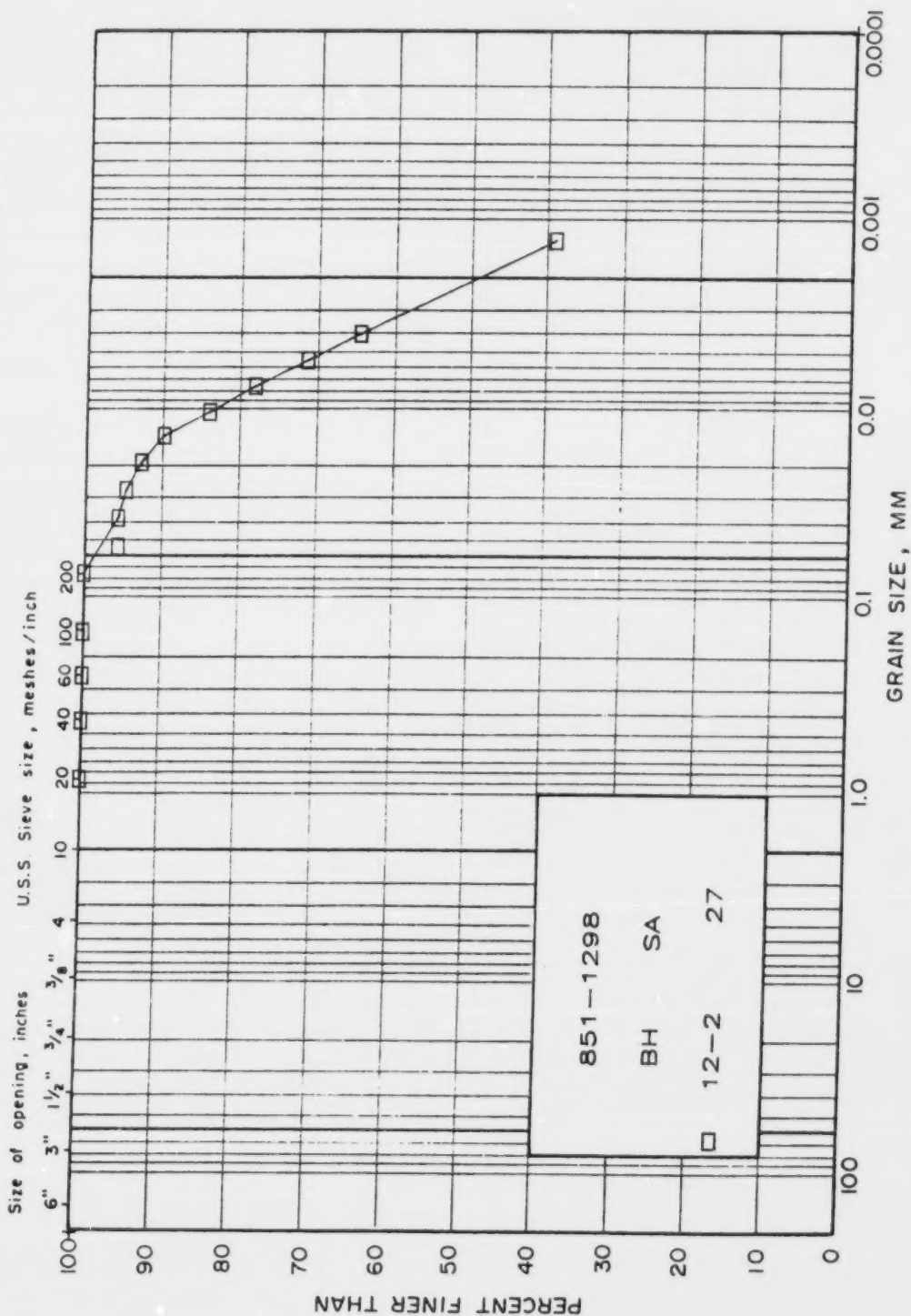
12-2 19

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GRAIN SIZE DISTRIBUTION

FIGURE 73

M.I.T. GRAIN SIZE SCALE



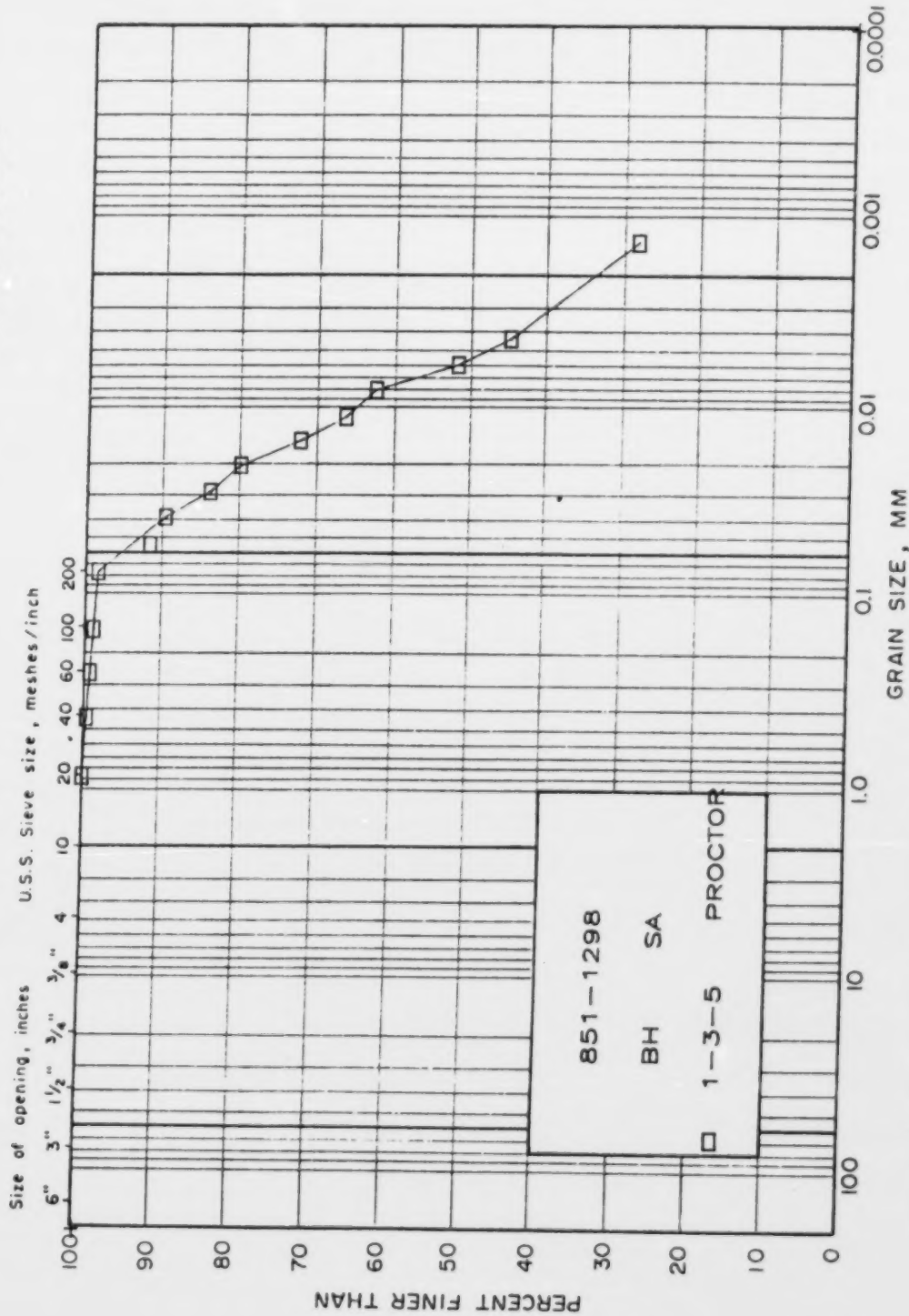
COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE 74

M.I.T. GRAIN SIZE SCALE

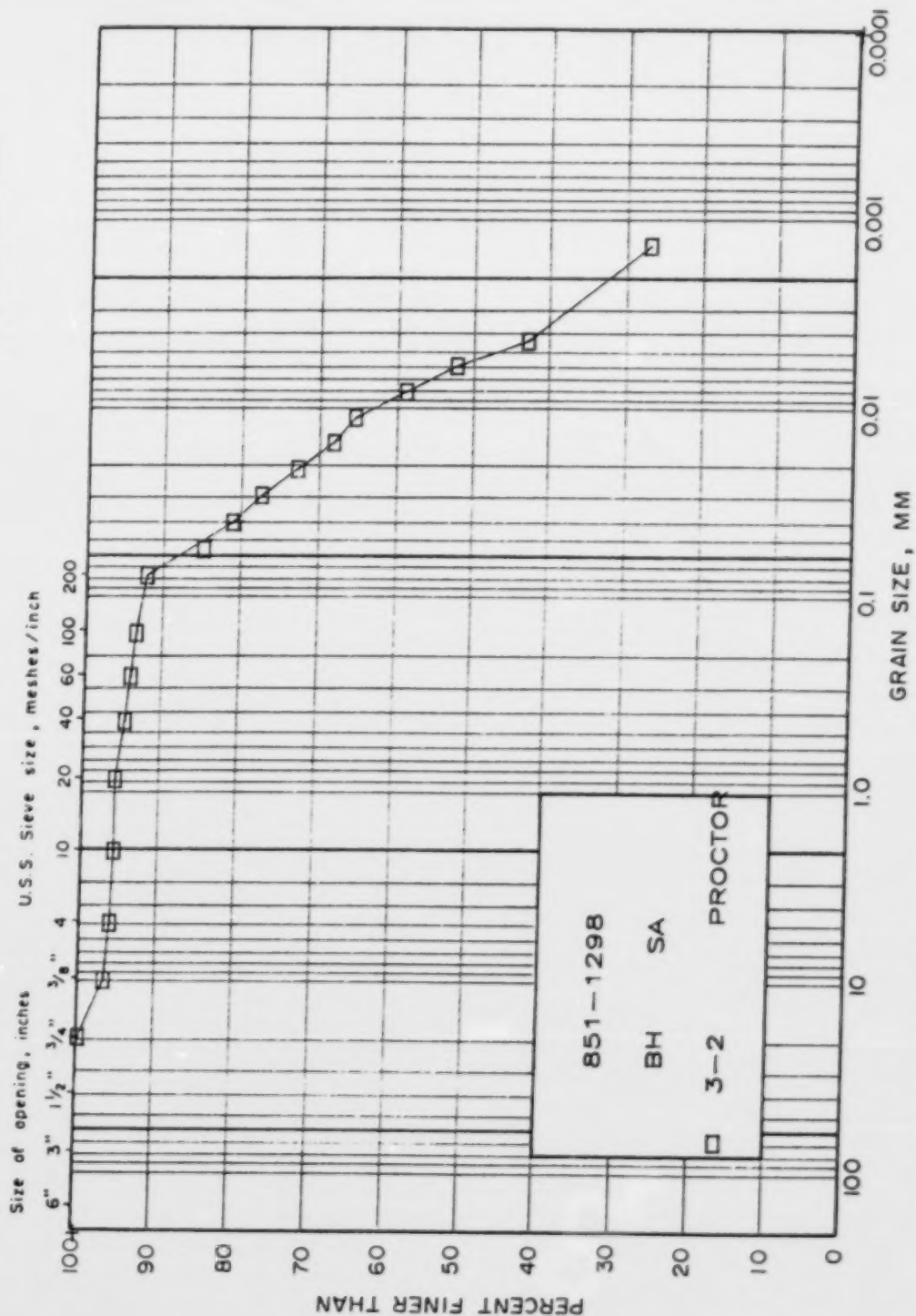


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GRAIN SIZE DISTRIBUTION

FIGURE 75

M.I.T. GRAIN SIZE SCALE



COBBLE SIZE	COARSE	MEDIUM	FINE	SAND SIZE			SILT SIZE		CLAY SIZE	
	GRAVEL SIZE			COARSE	MEDIUM	FINE	FINE GRAINED			

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May, 1986

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APPENDIX 1

COMPUTER DATA SHEETS

CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS

CYCLE A

86-05-06

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
 Project Number: 851-1298
 Sample Number: BH 5-2 SA 13

Sample A: A
 Sample B: B
 Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 in	AXIAL STRAIN %	STRESS DIAL READING .002 in	Deviator Stress kPa	Effective Principal Stress Ratio	Effective Shear Stress kPa	Effective Normal Stress kPa
0.0	0.0	330.7	130.9	0.0	0.0	0.00	0.0	0.00	1.00	0.0	199.8
0.5	-1.1		152.3	21.4	32.0	0.32	31.0	18.36	1.10	9.2	187.6
1.0	-1.8		157.8	26.9	51.5	0.51	55.0	32.51	1.19	16.3	189.2
1.5	-2.3		170.9	40.0	62.5	0.62	100.5	64.06	1.40	32.0	191.9
2.2	-3.2		211.5	80.6	110.0	1.10	217.0	127.50	2.07	63.7	182.9
2.5	-3.5		216.3	85.4	139.6	1.39	254.2	148.92	2.30	74.5	188.8
3.0	-3.9		220.5	89.6	162.9	1.63	272.8	159.44	2.45	79.7	189.9
3.5	-4.3		224.6	93.7	190.8	1.90	314.8	183.46	2.73	91.7	197.8
7.5	-5.7		224.6	93.7	219.2	2.19	351.2	204.00	2.92	102.0	208.1
37.5	-5.9		223.9	93.0	274.0	2.73	419.5	242.41	3.27	121.2	228.0
63.3	-6.0		221.2	90.3	297.5	2.97	445.5	256.81	3.34	128.4	237.9
			212.9	82.0	323.5	3.23	471.5	271.07	3.30	135.5	253.3
			208.1	77.2	337.5	3.37	446.5	256.33	3.09	128.2	250.8
LENGTH, INITIAL, cm	10.120		214.3	83.4	350.5	3.50	494.9	283.74	3.44	141.9	258.3
DIAMETER, cm	5.030		210.1	79.2	350.0	3.57	507.0	290.45	3.41	145.2	265.8
AREA, INITIAL, cm ²	19.874		201.9	71.0	300.0	3.79	525.1	300.13	3.33	150.1	278.9
VOLUME, INITIAL, cc	201.123		198.4	67.5	411.0	4.10	543.0	309.36	3.34	154.7	286.9
CONS. VOLUME CHANGE, cc	6.0		192.2	61.3	476.0	4.75	566.0	320.29	3.31	160.1	298.6
VOLUMETRIC STRN, cc	0.030		191.5	60.6	554.0	5.53	588.0	330.02	3.37	165.0	304.2
LENGTH, CONS, cm	10.019		180.8	57.9	596.0	5.95	597.0	333.58	3.35	166.8	300.7
AREA, CONS, cm ²	19.479		187.4	56.5	670.0	6.69	600.0	337.06	3.35	168.5	311.0
CONS. VOLUME, cc	195.123		175.7	44.8	722.0	7.21	615.0	339.04	3.19	169.5	324.5
PROVING RING kg/div	0.118		153.6	22.7	783.5	7.82	621.5	340.36	2.92	170.2	347.2
EFF. CELL PRESS, kPa	199.8		161.9	31.0	1165.0	11.63	651.0	341.79	3.02	170.9	339.7
			170.4	47.5	1190.0	11.88	668.0	349.72	3.30	174.9	327.1
stopped overnight at 3.23%			179.1	48.2	1229.0	12.27	669.8	349.12	3.30	174.6	326.1
restarted at 3.37%			173.6	42.7	1290.0	12.87	671.6	347.63	3.21	173.8	330.9
			180.5	49.6	1365.0	13.62	674.3	346.03	3.30	173.0	323.2
slowed to .25%/hr. at 7.82%			173.6	42.7	1429.0	14.26	676.8	344.74	3.19	172.4	329.4
increased to .5%/hr. at 11.63%			177.0	46.9	1503.0	15.00	679.0	342.80	3.24	171.4	324.4
slowed to .25%/hr. at 15.82%			177.0	46.9	1585.0	15.82	682.1	341.13	3.23	170.6	323.5
			172.9	42.0	1801.0	18.77	696.0	335.87	3.13	167.9	325.7

CYCLE B

86-05-06

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
 Project Number: 851-1298
 Sample Number: BH 5-2 SA 13

Sample A: A
 Sample B: B
 Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 mm	AXIAL STRAIN %	STRESS DIAL READING .002 mm	Deviator Stress kPa	Effective Principal Stress Ratio	Effective Shear Stress kPa	Effective Normal Stress kPa
0.0	0.0	620.1	199.8	0.0	0.0	0.00	0.0	0.00	1.00	0.0	400.3
0.5	-1.7		223.2	23.4	5.5	0.05	17.0	9.04	1.03	4.9	381.0
1.0	-2.4		227.4	27.6	10.0	0.10	40.0	23.15	1.06	11.6	384.3
1.5	-3.0		233.6	33.8	16.2	0.16	67.0	38.76	1.11	19.4	385.9
2.0	-3.8		241.1	41.3	21.9	0.22	105.9	61.23	1.17	30.6	389.6
2.4	-4.6		259.8	59.9	28.2	0.28	194.8	112.56	1.33	56.3	396.6
3.2	-5.0		274.9	75.1	35.5	0.35	260.0	150.12	1.46	75.1	400.3
3.9	-5.4		291.4	91.6	46.5	0.46	336.0	193.79	1.63	96.9	405.6
4.4	-5.6		314.9	115.1	61.7	0.61	421.2	242.56	1.85	121.3	406.5
5.9	-6.2		330.7	130.9	76.9	0.77	499.0	286.93	2.06	143.5	412.9
32.0	-7.0		343.1	143.3	90.0	0.90	554.8	318.60	2.24	159.3	416.3
			352.0	153.0	100.0	1.00	620.3	355.57	2.44	177.0	425.1
			364.5	164.7	132.1	1.32	682.2	390.10	2.66	195.0	430.7
			370.0	170.2	155.0	1.54	728.3	415.50	2.81	207.7	437.9
			376.2	176.4	187.0	1.86	765.0	435.02	2.94	217.5	441.4
slowed to .25%/hr. at 2.89%			377.6	177.8	219.0	2.18	786.1	445.57	3.00	222.0	445.3
			377.6	177.8	290.0	2.89	806.5	453.02	3.04	226.9	449.4
increased to .5%/hr at 6.34%			377.6	177.8	311.0	3.10	807.0	453.13	3.04	226.6	449.1
			385.2	185.3	417.2	4.16	803.9	446.46	3.00	223.2	438.2
			381.7	181.9	636.0	6.34	820.0	445.04	3.04	222.5	440.9
LENGTH, INITIAL, cm	10.15		396.2	196.4	657.0	6.55	843.0	456.50	3.24	228.2	432.2
DIAMETER, cm	5.10		391.3	191.5	716.2	7.14	843.3	453.70	3.17	226.9	435.6
AREA, INITIAL, cm ²	20.43		389.3	189.5	772.0	7.69	843.2	451.01	3.14	225.5	436.3
VOLUME, INITIAL, cc	207.4		391.3	191.5	811.5	8.09	844.0	449.51	3.15	224.8	433.5
CONS. VOLUME CHANGE,	7.0		393.4	193.6	851.0	8.48	845.0	448.12	3.17	224.1	430.7
VOLUMETRIC STRN, cc	0.03		393.4	193.6	871.0	8.68	845.7	447.51	3.16	223.6	430.4
LENGTH, CONS, cm	10.04		389.3	189.5	904.5	9.01	846.5	446.30	3.12	223.1	434.0
AREA, CONS, cm ²	19.97		392.0	192.2	934.8	9.31	847.9	445.55	3.14	222.0	430.8
CONS. VOLUME, cc	200.4		398.9	199.1	984.2	9.81	850.0	444.23	3.21	222.1	423.3
PROVING RING kg/div	0.118		392.7	192.9	1043.0	10.39	853.0	442.90	3.14	221.4	420.8
EFF. CELL PRESS. kPa	400.3		396.2	196.4	1073.9	10.70	853.0	441.30	3.16	220.7	424.6
			396.2	196.4	1093.5	10.90	854.0	440.93	3.16	220.5	424.4

CYCLE C

86-05-06

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Project Number: 851-1298

Sample A: A

Sample Number: BH 5-2 SA 13

Sample B: B

Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 mm	AXIAL STRAIN %	STRESS DIAL READING .002 mm	Deviator Stress kPa	Effective Principal Stress Ratio	Effective Shear Stress kPa	Effective Normal Stress kPa
0.0	0.0	930.0	130.9	0.0	0.0	0.00	0.0	0.00	1.00	0.0	799.9
0.5	-1.7		137.1	6.2	3.0	0.03	31.0	20.97	1.03	10.5	804.2
1.0	-2.4		144.0	13.1	12.0	0.12	52.0	35.14	1.04	17.6	804.4
1.5	-3.0		153.6	22.7	25.1	0.25	75.0	50.62	1.07	25.3	802.5
2.0	-3.9		163.3	32.4	37.5	0.37	91.0	61.34	1.08	30.7	798.2
2.7	-4.4		166.0	35.1	43.5	0.44	101.0	68.04	1.09	34.0	798.0
3.0	-4.9		171.6	40.7	53.0	0.53	108.0	72.69	1.10	36.3	795.6
4.9	-7.6		181.9	51.0	60.0	0.60	172.0	115.68	1.15	57.8	806.8
31.7	-10.3		212.9	82.0	78.0	0.78	302.0	202.91	1.28	101.5	819.4
			241.0	110.9	78.0	0.78	390.0	261.02	1.38	130.9	819.9
slowed to .25%/hr. at 3.59%			283.2	152.3	90.0	0.91	502.0	336.58	1.52	168.3	815.9
increased to .5%/hr at 7.21%			338.3	207.4	108.0	1.08	618.0	413.63	1.70	206.0	799.3
			354.1	223.2	127.0	1.27	708.0	472.96	1.82	236.5	813.1
LENGTH, INITIAL, cm	10.16		422.4	291.4	143.5	1.44	768.0	512.18	2.01	256.1	764.5
DIAMETER, cm	5.04		455.4	324.5	165.0	1.66	830.0	552.27	2.16	276.1	751.5
AREA, INITIAL, cm ²	19.95		496.0	365.9	194.0	1.94	884.0	586.52	2.35	293.3	727.3
VOLUME, INITIAL, cc	202.72		511.9	381.0	222.2	2.22	920.0	608.64	2.45	304.3	723.2
CONS. VOLUME CHANGE, %	10.30		544.3	413.4	256.2	2.56	952.0	627.62	2.62	313.8	700.3
VOLUMETRIC STRN, cc	0.05		557.4	426.5	289.3	2.90	970.0	637.31	2.71	318.7	692.1
LENGTH, CONS, cm	9.99		570.5	439.6	359.0	3.59	995.5	649.37	2.80	324.7	685.0
AREA, CONS, cm ²	19.28		579.4	448.5	379.0	3.79	981.0	638.58	2.82	319.3	670.6
CONS. VOLUME, cc	192.42		616.0	485.1	491.0	4.92	904.0	581.60	2.85	290.0	685.6
PROVING RING kg/div	0.133		613.2	482.3	720.0	7.21	1031.5	647.62	3.04	323.8	641.4
EFF. CELL PRESS, kPa	799.9		618.7	487.8	742.0	7.43	1054.0	660.18	3.11	330.1	642.2
			633.2	502.3	798.0	7.99	1056.0	657.43	3.21	328.7	626.3
			620.1	489.2	848.0	8.49	1077.0	666.85	3.15	333.4	644.1
			619.4	488.5	884.0	8.85	1085.0	669.16	3.15	334.6	646.0
			618.7	487.8	922.0	9.23	1092.0	670.66	3.15	335.3	647.4
			618.7	487.8	940.0	9.41	1094.0	670.56	3.15	335.3	647.4
			618.7	487.8	972.0	9.73	1098.0	670.63	3.15	335.3	647.4
			627.0	496.1	1000.0	10.01	1102.0	670.98	3.21	335.5	639.3
			616.6	485.7	1046.0	10.47	1106.0	669.97	3.13	335.0	649.1
			620.8	489.9	1100.0	11.01	1113.0	670.14	3.16	335.1	645.1
			620.1	489.2	1129.0	11.30	1116.0	669.75	3.16	334.9	645.6
			618.7	487.8	1147.7	11.49	1118.0	669.54	3.15	334.8	646.9

CYCLE A

06-05-06

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Project Number: 851-1298

Sample Number: BH-85-8-2 SA.4

Sample A: A

Sample B: B

Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P. kPa	Changed P.W.P. kPa	STRAIN DIAL READING .01 mm	AXIAL STRAIN %	STRESS DIAL READING .002 mm	Deviator Stress kPa	Effective Principal Stress Ratio	Shear Stress kPa	Effective Normal Stress kPa
0.0	0.0	287.3	62.0	0.0	0.0	0.000	0.0	0.00	1.00	0.0	225.3
0.5	-1.4		73.7	11.7	11.0	0.110	51.2	11.47	1.05	5.7	219.3
1.0	-2.3		75.1	13.1	40.0	0.399	73.8	16.40	1.00	8.2	220.4
1.5	-3.2		76.5	14.5	63.0	0.629	107.7	41.83	1.20	20.9	231.7
2.0	-3.9		88.2	26.2	81.9	0.817	212.8	47.33	1.24	23.7	222.8
2.5	-4.5		102.7	40.7	90.0	0.898	407.1	100.25	1.59	54.1	230.9
3.0	-4.9		111.6	49.6	90.0	0.978	551.5	122.46	1.70	61.2	236.9
3.5	-5.3		122.6	60.6	109.8	1.096	650.5	144.27	1.80	72.1	236.8
4.0	-5.6		130.2	68.2	122.5	1.223	760.0	170.11	2.00	85.1	242.1
5.0	-5.7		137.8	75.8	138.9	1.386	874.0	193.27	2.29	96.6	246.1
6.3	-6.0		141.9	79.9	156.2	1.559	976.0	215.45	2.40	107.7	253.1
21.6	-6.8		144.0	82.0	174.1	1.738	1065.2	234.71	2.64	117.4	260.7
42.2	-7.2		145.4	83.4	194.3	1.939	1155.5	254.09	2.79	127.0	269.0
LENGTH, INITIAL, cm	10.140		145.4	83.4	200.1	1.997	1133.9	249.19	2.76	124.6	266.5
DIAMETER, cm	5.010		145.4	83.4	213.1	2.127	1067.0	234.18	2.65	117.1	259.0
AREA, INITIAL, cm ²	19.716		145.4	83.4	214.2	2.138	1132.2	240.46	2.75	124.2	266.1
VOLUME, INITIAL, cc	199.922		140.8	86.8	215.8	2.154	1196.0	262.42	2.89	131.2	269.7
CONS. VOLUME CHANGE,	7.2		146.8	84.8	221.1	2.207	1272.0	270.94	2.90	139.5	280.0
VOLUMETRIC STRN, cc	0.036		145.4	83.4	226.3	2.259	1313.0	287.78	3.03	143.9	285.8
LENGTH, CONS. cm	10.018		145.4	83.4	232.3	2.319	1349.5	295.60	3.08	147.0	289.7
AREA, CONS. cm ²	19.243		144.0	82.0	243.0	2.426	1398.0	305.89	3.13	152.9	296.2
CONS. VOLUME, cc	192.722		144.0	82.0	249.0	2.485	1420.0	310.51	3.17	155.3	298.6
PROVING RING kg/div	0.044		143.3	81.3	256.0	2.555	1445.0	315.75	3.19	157.9	301.9
EFF. CELL PRESS. kPa	225.3		143.3	81.3	265.0	2.645	1475.0	322.01	3.24	161.0	305.0
			140.6	78.6	275.0	2.745	1512.0	329.75	3.25	164.9	311.6
stopped overnight at 1.94%			141.2	79.2	283.4	2.829	1543.0	336.22	3.30	168.1	314.2
restarted at 2.00%			138.5	76.5	303.3	3.027	1606.0	349.23	3.35	174.6	323.4
			137.8	75.0	319.0	3.184	1650.0	359.96	3.41	180.0	329.5
			136.4	74.4	340.0	3.394	1724.0	373.40	3.48	186.7	337.6
			131.6	69.6	365.7	3.650	1805.0	389.99	3.50	195.0	350.7
			130.2	68.2	389.0	3.891	1893.0	405.82	3.58	202.9	360.0
			126.1	64.1	409.3	4.086	1943.0	417.91	3.59	209.0	370.2
			123.3	61.3	430.0	4.300	2033.0	435.92	3.66	218.0	381.9
			117.1	55.1	464.3	4.635	2112.0	451.65	3.65	225.8	396.0
			113.0	51.0	492.0	4.911	2195.0	468.04	3.69	234.0	400.3
			108.2	46.2	525.0	5.240	2291.0	486.02	3.72	243.4	422.5
			102.0	40.0	557.0	5.560	2379.0	503.99	3.72	252.0	437.3
slowed to .05%/hr. at 6.16%			89.9	26.9	617.5	6.164	2635.0	554.46	3.79	277.2	475.6
			90.2	26.2	641.0	6.398	2635.0	553.08	3.78	276.5	475.6
			71.0	9.0	719.5	7.182	2670.0	555.73	3.57	277.9	494.2
			57.7	-4.1	800.0	8.784	3054.0	624.69	3.72	312.3	541.6
			58.6	-3.4	891.0	8.894	3073.0	627.82	3.74	313.9	542.6
			53.7	-8.3	911.0	9.573	3098.0	631.54	3.70	315.8	549.3
			54.4	-7.6	927.3	9.256	3116.5	634.17	3.72	317.1	549.9
			53.0	-8.9	940.0	9.383	3128.3	635.68	3.71	317.0	552.1
			53.0	-8.9	946.0	9.443	3136.0	636.83	3.72	318.4	552.7
			50.3	-11.7	959.1	9.573	3146.2	637.97	3.69	319.0	556.0
			49.6	-12.4	960.0	9.662	3153.0	638.73	3.69	319.4	557.1
			49.6	-12.4	980.0	9.782	3163.0	639.90	3.69	319.9	557.6

CYCLE A

86-25-26

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Project Number: 851-1298

Sample Number: BH.85-8-2 SA.4

Sample A: A

Sample B: B

Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 mm	AXIAL STRAIN %	STRESS DIAL READING .002 mm	Deviator Stress kPa	Effective Principal Stress Ratio	Shear Stress kPa	Effective Normal Stress kPa
			48.2	-13.9	992.0	9.902	3175.0	641.48	3.68	320.7	559.8
			48.2	-13.8	1008.2	10.064	3184.2	642.18	3.69	321.1	560.2
maximum capacity of proving ring reached at 10.23%			47.5	-14.5	1020.8	10.189	3194.0	643.26	3.68	321.6	561.4
			47.5	-14.5	1025.0	10.231	3197.0	643.56	3.68	321.8	561.5

CYCLE B

86-05-06

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Project Number: 851-1298

Sample Number: BH.85-8-2 SA.4

Sample A: A

Sample B: B

Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 mm	AXIAL STRAIN %	STRESS DIAL READING .002 mm	Deviator Stress kPa	Effective Principal Stress Ratio	Shear Stress kPa	Effective Normal Stress kPa
0.0	0.0	580.0	130.9	0.0	0.0	0.000	0.0	0.00	1.00	0.0	449.9
0.5	-1.2		165.4	34.4	19.0	0.190	4.0	6.17	1.01	3.1	418.5
1.0	-2.0		167.4	36.5	44.9	0.440	4.0	6.15	1.01	3.1	416.5
1.5	-2.8		172.2	41.3	70.0	0.699	4.3	6.60	1.02	3.3	411.9
2.0	-3.3		175.0	44.1	53.0	0.529	10.0	15.37	1.04	7.7	413.5
2.5	-3.6		203.3	72.3	62.0	0.619	80.0	122.83	1.33	61.4	439.0
3.0	-3.8		248.0	117.1	70.1	0.700	167.0	256.20	1.77	128.1	460.9
3.5	-4.0		276.3	145.4	95.0	0.940	235.0	359.62	2.18	179.8	484.3
4.2	-4.1		305.2	174.3	112.0	1.118	290.0	443.03	2.61	221.5	497.1
5.5	-4.2		316.2	185.3	132.0	1.318	341.0	519.89	2.97	259.9	524.5
9.5	-4.3		323.0	192.9	153.0	1.527	382.0	581.16	3.26	290.6	547.6
13.2	-4.4		324.5	193.6	177.0	1.767	417.2	633.17	3.47	316.6	572.9
65.2	-4.4		323.1	192.2	200.2	1.999	445.0	673.76	3.61	336.9	594.5
			314.9	184.0	226.0	2.264	460.3	707.12	3.66	353.6	619.5
stopped overnight at 2.26%			314.9	184.0	232.0	2.316	451.2	680.94	3.56	340.5	606.4
restarted at 2.32%			299.7	168.0	310.0	3.095	91.5	136.99	1.49	68.5	349.6
			295.6	164.7	313.0	3.125	131.0	196.06	1.69	98.0	383.3
			305.2	174.3	316.5	3.160	167.7	250.90	1.91	125.4	401.0
			316.9	186.0	322.4	3.219	218.7	327.01	2.24	163.5	427.4
			322.5	191.5	327.0	3.265	249.0	372.14	2.44	186.1	444.4
LENGTH, INITIAL, cm	10.09		320.7	197.7	330.0	3.302	275.0	410.83	2.63	205.4	457.6
DIAMETER, cm	5.05		334.2	203.3	338.0	3.382	319.0	476.17	2.93	238.1	484.7
AREA, INITIAL, cm ²	20.03		336.9	206.0	343.2	3.426	340.0	507.29	3.08	253.6	497.5
VOLUME, INITIAL, cc	202.1		336.9	206.0	348.0	3.474	360.1	548.94	3.25	274.5	518.4
CONS. VOLUME CHANGE,	4.4		336.9	206.0	355.4	3.548	382.0	569.23	3.33	294.6	529.5
VOLUMETRIC STRN, cc	0.02		336.2	205.3	365.0	3.644	407.0	605.88	3.48	302.9	547.5
LENGTH, CONS, cm	10.02		333.5	202.6	373.0	3.732	423.2	629.43	3.54	314.7	562.0
AREA, CONS, cm ²	19.74		330.7	199.8	395.0	3.943	451.0	669.30	3.68	334.6	584.7
CONS. VOLUME, cc	197.7		329.3	198.4	412.0	4.113	466.8	691.52	3.75	343.0	597.2
PROVING RING kg/div	0.311		323.0	192.9	437.0	4.363	484.7	716.17	3.79	358.1	615.1
EFF. CELL PRESS, kPa	449.9		317.6	186.7	467.0	4.662	503.0	740.80	3.81	370.4	633.6
			310.7	179.0	497.0	4.962	515.9	757.50	3.80	378.7	648.8
			308.7	177.8	521.1	5.202	526.0	770.37	3.83	385.2	657.3
			299.7	168.0	555.3	5.544	539.5	787.30	3.80	393.6	674.7
			294.9	164.0	590.3	5.893	550.6	800.52	3.80	400.3	686.2
			290.1	159.2	625.3	6.242	561.7	813.63	3.80	406.8	697.6
			283.2	152.3	665.9	6.648	572.0	826.12	3.78	413.1	710.7
			276.3	145.4	704.0	7.029	583.3	837.84	3.75	419.0	723.4
slowed to .25%/hr. at 7.74%			283.2	152.3	775.0	7.737	593.0	845.20	3.84	422.6	720.3
			291.0	158.9	804.0	8.026	588.0	835.52	3.79	417.8	716.8
			285.3	154.4	917.0	9.155	613.5	861.06	3.73	430.5	746.1
increased to .5%/hr. at 11.45%			239.1	108.2	1147.0	11.451	665.0	909.75	3.66	454.9	796.6
			232.2	101.3	1172.0	11.700	680.0	927.65	3.66	463.8	812.4
			226.7	95.0	1232.0	12.299	692.0	938.70	3.65	469.3	823.5
			219.1	88.2	1290.5	12.883	702.0	944.03	3.61	472.4	834.1
			212.2	81.3	1335.0	13.328	707.1	946.84	3.57	473.4	842.0
			210.1	79.2	1376.0	13.737	710.0	946.24	3.55	473.1	843.8
			207.4	76.5	1398.0	13.957	710.0	943.03	3.53	471.9	845.3
			206.7	75.0	1434.0	14.316	709.0	938.56	3.51	469.3	843.4

CYCLE B

86-05-06

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Project Number: 851-1298

Sample Number: BH.85-8-2 SA.4

Sample A: A

Sample B: B

Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 mm	AXIAL STRAIN %	STRESS DIAL READING .002 mm	Effective Deviator Stress kPa	Effective Principal Stress Ratio	Effective Shear Stress kPa	Effective Normal Stress kPa
			206.7	75.8	1467.5	14.650	708.9	934.77	3.50	467.4	841.5
			206.7	75.8	1521.5	15.189	710.8	931.35	3.49	465.7	839.8
			205.3	74.4	1586.0	15.833	709.0	921.94	3.46	461.0	836.5
			205.3	74.4	1620.0	16.173	709.3	918.61	3.45	459.3	834.8

CYCLE C

96-05-06

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Project Number: 851-1290

Sample Number: BH.85-6-2 SA.4

Sample A: A

Sample B: B

Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 mm	AXIAL STRAIN %	STRESS DIAL READING .002 mm	Deviator Stress kPa	Effective Principal Stress Ratio	Shear Stress kPa	Effective Normal Stress kPa
0.0	0.0	711.7	130.9	0.0	0.0	0.000	0.0	0.00	0.65	0.0	895.7
0.5	-2.2		287.3	156.4	69.0	0.695	618.0	423.69	1.15	211.8	951.1
1.0	-3.5		317.6	186.7	78.8	0.794	638.0	436.96	1.17	218.5	927.5
1.5	-4.5		335.5	204.6	83.8	0.844	678.0	464.12	1.22	232.1	923.1
2.0	-5.3		355.5	224.6	89.0	0.896	822.0	562.40	1.37	281.2	952.3
2.5	-5.9		378.9	248.0	96.0	0.967	877.0	599.60	1.44	299.8	947.5
3.0	-6.6		394.8	263.9	102.0	1.027	1016.0	694.21	1.60	347.1	978.9
3.5	-7.0		410.2	287.3	110.0	1.100	1062.0	725.05	1.67	362.5	970.9
4.0	-7.5		440.5	317.6	124.0	1.249	1132.0	771.74	1.79	385.9	963.9
5.0	-8.1		465.8	334.8	134.0	1.350	1175.0	800.24	1.87	400.1	961.0
5.6	-8.3		480.5	357.6	149.0	1.501	1226.0	833.70	1.96	416.8	955.0
6.6	-8.6		512.6	381.7	174.0	1.753	1290.0	874.97	2.09	437.5	951.5
31.4	-11.3		520.9	390.0	199.0	2.004	1329.5	899.46	2.16	449.7	955.5
LENGTH, INITIAL, cm	10.12		566.4	435.4	219.0	2.206	1374.0	927.65	2.33	463.8	924.1
DIAMETER, cm	5.00		561.5	430.6	253.0	2.548	1402.0	943.24	2.35	471.6	936.7
AREA, INITIAL, cm ²	19.64		550.1	427.2	299.0	3.012	1434.0	960.10	2.38	480.1	940.6
VOLUME, INITIAL, cc	198.73		571.9	441.0	332.3	3.347	1452.0	968.87	2.44	484.4	939.2
CONS. VOLUME CHANGE,	11.30		576.7	445.8	363.6	3.662	1460.0	971.03	2.46	485.5	935.4
VOLUMETRIC STRN, cc	0.06		580.0	449.9	379.1	3.818	1462.1	970.85	2.47	485.4	931.2
LENGTH, CONS, cm	9.93		569.8	438.9	445.0	4.402	1462.0	964.09	2.42	482.0	938.8
AREA, CONS., cm ²	10.89		569.1	430.2	465.5	4.689	1460.5	961.02	2.41	480.5	938.0
CONS. VOLUME, cc	187.43		525.0	394.1	612.0	6.164	1136.0	735.92	1.84	360.0	869.6
PROVING RING kg/div	0.133		627.0	496.1	872.0	8.783	1055.0	664.37	1.87	332.2	731.0

CYCLE A

00-00-00

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Project Number: 851-1298

Sample Number: BH. 85-8-2 SA. 22

Sample A: A

Sample B: B

Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 in	AXIAL STRAIN %	STRESS DIAL READING .002 in	Deviator Stress kPa	Effective Principal Stress Ratio	Shear Stress kPa	Effective Normal Stress kPa
0.0	0.0	381.0	130.9	0.0	0.0	0.00	0.0	0.00	1.00	0.0	250.1
0.5	-1.2		157.8	26.9	20.0	0.20	52.0	11.77	1.05	5.9	229.1
1.0	-1.8		167.4	36.5	22.1	0.22	106.3	24.05	1.11	12.0	225.6
1.5	-2.6		177.8	46.8	26.1	0.26	184.0	41.62	1.20	20.8	224.1
2.0	-4.2		188.8	57.9	30.5	0.31	234.5	53.02	1.28	26.5	218.7
2.5	-4.2		206.7	75.8	41.0	0.41	308.0	69.56	1.40	34.8	209.1
3.3	-5.4		220.5	89.6	54.0	0.54	360.0	81.20	1.51	40.6	201.1
4.2	-6.8		226.0	95.1	67.5	0.68	387.2	87.21	1.56	43.6	198.6
4.5	-7.5		232.2	101.3	75.0	0.76	417.0	93.85	1.63	46.9	195.7
6.6	-9.6		246.0	115.1	101.0	1.02	464.0	104.15	1.77	52.1	187.1
11.9	-12.2		254.2	123.3	126.5	1.27	502.0	112.39	1.89	56.2	183.0
13.1	-12.4		255.6	124.7	154.0	1.55	535.0	119.44	1.95	59.7	185.1
33.4	-14.7		268.0	137.1	185.0	1.86	573.0	127.52	2.13	63.8	176.7
LENGTH, INITIAL, cm	10.170		273.5	142.6	220.0	2.30	618.4	137.02	2.27	68.5	176.0
DIAMETER, cm	4.990		274.9	144.0	261.0	2.63	651.0	143.75	2.35	71.9	178.0
AREA, INITIAL, cm ²	19.559		274.9	144.0	287.7	2.90	675.0	148.63	2.40	74.3	180.4
VOLUME, INITIAL, cc	198.915		276.3	145.4	298.2	3.01	684.2	150.50	2.44	75.2	180.0
CONS. VOLUME CHANGE, cc	14.7		279.7	148.0	330.0	3.33	713.9	156.51	2.55	78.3	179.5
VOLUMETRIC STRN, cc	0.074		286.6	155.7	362.0	3.65	743.0	162.35	2.72	81.2	175.6
LENGTH, CONS, cm	9.919		294.9	164.0	472.5	4.76	805.0	173.86	3.02	86.9	173.0
AREA, CONS., cm ²	18.595		292.1	161.2	683.0	6.89	878.0	185.40	3.09	92.7	181.6
CONS. VOLUME, cc	184.215		289.4	158.5	694.0	7.00	876.0	184.76	3.02	92.4	184.0
PROVINS RING kg/div	0.043		289.4	158.5	706.0	7.12	892.1	187.91	3.05	94.0	185.6
EFF. CELL PRESS. kPa	250.1		287.3	156.4	725.0	7.31	899.0	188.97	3.02	94.5	188.2
			283.2	152.3	762.0	7.68	905.9	189.66	2.94	94.8	192.7
slowed to .25%/hr at 3.65%			283.2	152.3	786.0	7.92	909.0	189.81	2.94	94.9	192.7
			288.7	157.8	818.5	8.25	914.7	190.32	3.06	95.2	187.5
increase to .5%/hr at 6.89%			288.0	157.1	845.2	8.52	917.2	190.28	3.05	95.1	188.1
			288.0	157.1	915.0	9.22	921.6	189.72	3.04	94.9	187.9
			284.6	153.6	1011.0	10.20	925.0	188.37	2.95	94.2	190.6
			289.4	158.5	1064.0	10.73	926.0	187.47	3.05	93.7	185.4
			301.0	170.9	2045.2	20.62	836.5	150.59	2.90	75.3	154.5

CYCLE 8

80-85-86

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Project Number: 851-1298

Sample Number: BH. 85-8-2 SA. 22

Sample A: A

Sample B: B

Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 in	AXIAL STRAIN %	STRESS DIAL READING .002 in	Deviator Stress kPa	Effective Principal Stress Ratio	Shear Stress kPa	Effective Normal Stress kPa
0.0	0.0	599.4	199.8		0.0	0.00	0.0	0.00	1.00	0.0	399.6
0.5	-2.0		199.8	0.0	0.0	0.00	0.0	0.00	1.00	0.0	399.6
1.0	-3.0		215.7	15.9	3.9	0.04	4.0	6.53	1.02	3.3	387.0
1.5	-4.0		224.6	24.8	12.9	0.13	7.9	12.89	1.03	6.4	381.2
2.0	-5.0		234.9	35.1	22.3	0.22	14.2	23.15	1.06	11.6	376.0
2.5	-5.0		263.2	63.4	30.9	0.31	41.0	66.80	1.20	33.4	369.6
3.0	-6.0		285.2	85.4	37.2	0.37	61.0	99.32	1.32	49.7	363.8
3.5	-7.7		312.1	112.3	49.0	0.49	80.0	130.10	1.45	65.0	352.3
4.0	-9.0		351.4	151.6	70.0	0.70	98.2	159.35	1.64	79.7	327.7
5.5	-10.4		370.7	170.9	85.9	0.86	106.5	172.54	1.75	86.3	315.0
11.3	-14.9		387.2	187.4	105.8	1.06	114.0	184.32	1.97	92.2	304.4
			407.2	207.4	141.5	1.42	124.0	199.76	2.04	99.9	292.1
			421.7	221.9	176.2	1.77	132.2	212.22	2.19	106.1	283.8
			434.0	234.9	210.8	2.12	139.2	222.66	2.35	111.3	276.0
			447.2	247.3	253.0	2.55	147.1	234.20	2.54	117.1	269.4
			449.2	249.4	300.4	3.10	156.3	247.51	2.65	123.7	273.9
slowed to .25%/hr at 4.76%			454.0	254.2	349.0	3.51	162.2	255.77	2.76	127.9	273.2
			457.5	257.7	383.4	3.86	167.2	262.71	2.85	131.3	273.3
increase to .52%/hr at 0.69%			459.6	259.8	398.7	4.01	169.1	265.27	2.90	132.6	272.5
			450.9	259.1	473.0	4.76	179.0	270.61	2.98	139.3	279.8
LENGTH, INITIAL, cm	10.19		462.3	262.5	610.0	6.22	189.0	289.67	3.11	144.8	281.9
DIAMETER, cm	5.00		468.5	268.7	864.0	8.69	202.0	301.42	3.30	150.7	281.6
AREA, INITIAL, cm ²	19.64		464.4	264.6	875.8	8.81	206.0	306.99	3.27	153.5	288.5
VOLUME, INITIAL, cc	200.1		467.1	267.3	892.3	8.98	208.1	309.55	3.34	154.8	287.0
CONS. VOLUME CHANGE,	14.9		462.3	262.5	916.0	9.22	208.1	308.74	3.25	154.4	291.5
VOLUMETRIC STRN, cc	0.07		467.0	268.0	959.0	9.65	208.5	307.86	3.34	153.9	285.5
LENGTH, CONS, cm	9.94		466.4	266.6	986.4	9.93	208.9	307.51	3.31	153.7	286.7
AREA, CONS, cm ²	10.66		460.2	260.4	1024.0	10.30	209.5	307.10	3.21	153.5	292.7
CONS. VOLUME, cc	185.2		466.4	266.6	1053.0	10.60	210.0	306.83	3.31	153.4	286.4
PROVING RING ke/div	0.311		464.4	264.6	1132.0	11.39	211.0	305.55	3.26	152.0	287.0
EFF. CELL PRESS, kPa	399.6		467.1	267.3	1240.9	12.49	213.1	304.77	3.30	152.4	284.7
			464.4	264.6	1298.0	13.06	214.0	304.05	3.25	152.0	287.0

CYCLE C

20-40-40

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
 Project Number: 851-1298
 Sample Number: BH. 85-8-2 SA. 22

Sample A: A
 Sample B: B
 Sample C: C

Square Root of Time min	TOTAL Volume Change cc	Cell Pressure kPa	Total P.W.P kPa	Changed P.W.P kPa	STRAIN DIAL READING .01 mm	AXIAL STRAIN %	STRESS DIAL READING .002 mm	Deviator Stress kPa	Effective Principal Stress Ratio	Shear Stress kPa	Effective Normal Stress kPa
0.0	0.0	711.7	62.0	0.0	0.0	0.00	0.0	0.00	1.00	0.0	649.7
0.5	-2.0		86.1	24.1	14.0	0.14	31.0	19.29	1.03	9.6	635.2
1.0	-3.1		91.6	29.6	33.2	0.34	50.6	31.43	1.05	15.7	635.8
1.5	-4.2		96.5	34.4	43.0	0.44	56.2	34.87	1.06	17.4	632.7
2.0	-5.2		126.1	64.1	49.5	0.51	137.0	84.94	1.14	42.5	628.1
2.5	-6.4		158.5	96.5	58.0	0.59	215.0	133.19	1.24	66.6	619.8
3.0	-7.7		189.5	127.5	68.0	0.70	282.0	174.51	1.33	87.3	609.5
3.5	-9.4		212.9	150.9	77.1	0.79	319.0	197.23	1.40	98.6	597.4
4.0	-10.4		243.2	181.2	90.3	0.92	364.0	224.74	1.48	112.4	588.9
5.1	-12.4		284.6	222.5	112.0	1.15	423.0	260.58	1.61	130.3	557.4
8.9	-16.8		312.8	250.8	137.5	1.41	464.0	285.89	1.71	142.5	541.4
14.6	-19.4		347.9	285.9	163.0	1.67	494.0	302.72	1.83	151.4	515.1
36.2	-21.0		376.9	314.9	194.0	1.99	525.3	320.86	1.96	160.4	495.3
LENGTH, INITIAL, cm	10.12		400.3	338.3	243.0	2.49	554.2	336.78	2.08	168.4	479.8
DIAMETER, cm	5.04		418.9	356.9	279.0	2.86	573.0	346.89	2.18	173.4	466.2
AREA, INITIAL, cm ²	19.95		432.0	370.0	309.0	3.16	585.0	353.03	2.26	176.5	456.2
VOLUME, INITIAL, cc	201.92		430.6	368.6	323.7	3.31	589.9	355.44	2.26	177.7	458.8
CONS. VOLUME CHANGE,	21.00		452.0	390.0	390.0	3.99	612.0	366.16	2.41	183.1	442.0
VOLUMETRIC STRN, cc	0.10		469.2	407.2	495.0	5.07	623.0	368.57	2.52	184.3	426.0
LENGTH, CONS, cm	9.77		485.1	423.0	660.0	6.76	650.0	377.70	2.67	188.9	415.5
AREA, CONS, cm ²	18.57		483.7	421.7	667.0	6.83	654.9	380.26	2.67	190.1	418.2
CONS. VOLUME, cc	180.92		489.2	427.2	671.0	6.87	680.0	394.66	2.77	197.3	419.8
PROVING RING kg/div	0.118		485.1	423.0	673.7	6.90	691.0	400.92	2.77	200.5	427.1
EFF. CELL PRESS, kPa	649.7		487.1	425.1	739.0	7.56	676.5	389.69	2.73	194.8	419.4
			487.1	425.1	764.0	7.82	678.0	389.48	2.73	194.7	419.3
slowed to .25%/hr at 3.99%			489.9	427.9	797.0	8.17	680.0	389.16	2.75	194.6	416.4
			489.2	427.2	824.0	8.43	681.0	388.59	2.75	194.3	416.8
increase to .5%/hr at 6.76%			489.2	427.2	899.0	9.20	684.5	387.31	2.74	193.7	416.2
			494.7	432.7	995.9	10.19	691.1	386.78	2.78	193.4	418.4
			496.1	434.1	1052.0	10.77	694.0	385.92	2.79	193.0	408.6
			509.9	447.9	1962.0	20.08	696.2	346.73	2.72	173.4	375.2

May, 1986

851-1298

APPENDIX 2

COMPUTER DATA SHEETS

DIRECT SHEAR TESTS

CYCLE A

86-25-88

DIRECT SHEAR TESTS

PROJECT NUMBER 851-1298		BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER 85-3-2						Ring	Height	Stress
SAMPLE NUMBER	6	length,mm	59.50			A 0.308	24.28	300.0
SAMPLE DEPTH,m	4.8-5.1	width,mm	59.50	AREA,mm^2	3548.25	B 0.149	22.24	599.0
TEST DATE	85-03-86	height,mm	25.20	VOLUME,cc	89.27	C 0.149	21.10	999.7

Time min	Square Root of Time / min	Normal Dial .002mm	Normal Displ. mm	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. mm	Normal Dial .002mm	Volume Strain %	Shear stress kPa
0.00	0.0	2500.0	0	0.0	0.0	0.000	1200.0	0.00	0.0
0.25	0.5	2200.0	-0.600	4.0	9.0	0.022	1194.9	-0.042	7.7
3.00	1.7	2129.0	-0.742	14.9	34.0	0.081	1193.5	-0.053	29.0
23.00	4.8	2071.0	-0.858	33.5	64.1	0.207	1176.0	-0.198	54.7
92.00	9.6	2053.0	-0.894	46.0	79.0	0.302	1167.9	-0.264	67.4
211.00	14.5	2043.0	-0.914	55.0	87.5	0.375	1160.0	-0.329	74.6
275.00	16.6	2042.0	-0.916	69.1	100.0	0.491	1154.1	-0.378	85.3
1262.00	35.5	2041.0	-0.918	109.0	124.0	0.842	1127.0	-0.601	105.8
				122.5	129.1	0.967	1120.2	-0.657	110.1
				143.0	136.2	1.166	1112.0	-0.725	116.2
				162.0	140.9	1.338	1100.0	-0.758	120.2
				182.2	144.2	1.534	1098.0	-0.940	123.0
				214.0	148.0	1.844	1091.0	-0.998	126.3
				215.0	143.5	1.863	1083.8	-0.957	122.4
				225.2	149.2	1.954	1082.9	-0.965	127.3
				242.2	150.2	2.122	1078.9	-0.998	129.1
				260.9	149.2	2.311	1078.0	-0.998	127.3
				291.1	145.0	2.621	1076.9	-1.014	123.7
				315.3	141.0	2.871	1069.5	-1.075	120.3
				354.2	133.2	3.276	1063.5	-1.124	113.6
				386.8	128.0	3.612	1059.0	-1.161	109.2
				413.0	124.1	3.882	1055.3	-1.192	105.9
				472.0	121.1	4.478	1053.0	-1.211	103.3

stopped overnight at 1.84 mm
restarted at 1.86 mm

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER	85-3-2					Ring	Height	Stress
SAMPLE NUMBER	6	length,mm	59.50			A	0.308	24.28
SAMPLE DEPTH, m	4.8-5.1	width,mm	59.50	AREA,mm^2	3540.25	B	0.149	22.24
TEST DATE	85-03-06	height,mm	25.20	VOLUME,cc	89.27	C	0.149	21.10

Time min	Square Root of Time / min	Normal Dial .002mm	Normal Displ. mm	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. mm	Normal Dial .002mm	Volume Strain %	Shear stress kPa
0.00	0.0	2900.0	0.000	0.0	0.0	0.000	1400.0	0.000	0.0
1.00	1.0	1464.0	-2.872	12.1	7.8	0.105	1398.2	-0.016	3.2
2.00	1.4	1452.0	-2.896	27.1	33.0	0.205	1399.0	-0.009	13.6
3.00	1.7	1449.0	-2.902	45.5	83.5	0.288	1399.0	-0.009	34.5
6.00	2.4	1441.0	-2.918	54.9	113.0	0.323	1398.5	-0.013	46.6
64.00	8.0	1429.0	-2.942	67.8	160.5	0.357	1398.2	-0.016	66.2
128.00	11.3	1425.0	-2.950	82.9	213.0	0.403	1398.5	-0.013	97.9
1420.00	37.7	1420.0	-2.960	123.5	308.0	0.619	1393.0	-0.063	127.1
				134.2	331.7	0.679	1391.7	-0.075	136.9
				159.9	376.0	0.847	1390.0	-0.090	155.2
				177.9	401.2	0.977	1388.5	-0.107	165.0
				200.9	423.9	1.161	1385.0	-0.135	174.9
				229.0	439.0	1.412	1380.5	-0.175	181.2
				230.3	407.2	1.489	1376.9	-0.208	180.0
				246.9	453.0	1.563	1376.9	-0.208	187.0
				264.8	464.0	1.720	1375.2	-0.223	191.5
				283.1	467.1	1.897	1372.9	-0.244	192.0
				309.9	462.1	2.175	1367.0	-0.297	190.7
				340.2	471.0	2.460	1365.3	-0.312	194.4
				379.3	469.3	2.854	1362.7	-0.335	193.7
				400.2	460.0	3.172	1360.5	-0.355	189.8
				442.0	459.7	3.581	1359.0	-0.369	189.7
				461.0	454.3	3.781	1358.0	-0.378	187.5

stopped overnight at 1.41 mm
restarted at 1.49 mm

CYCLE C

86-25-28

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER	85-3-2					Ring	Height	Stress
SAMPLE NUMBER	6	length,mm	59.50		A	0.308	24.28	300.0
SAMPLE DEPTH,m	4.8-5.1	width,mm	59.50	AREA,mm^2	3542.25	B	0.149	22.24
TEST DATE	85-03-86	height,mm	25.20	VOLUME,cc	89.27	C	0.149	21.10

Time min	Square Root of Time / min	Normal Dial .002mm	Normal Displ. mm	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. mm	Normal Dial .002mm	Volume Strain %	Shear stress kPa
0.00	0.0	3123.0	0.000	0.0	0.0	0.000	1500.0	0.000	0.0
0.25	0.5	2460.0	-1.326	4.5	18.8	0.007	1477.5	-0.213	7.8
0.50	0.7	2320.0	-1.606	10.1	43.9	0.013	1474.8	-0.239	19.1
1.00	1.0	1420.0	-3.406	20.6	87.0	0.032	1473.0	-0.256	35.9
1.50	1.2	1245.0	-3.756	31.2	128.9	0.054	1470.8	-0.277	53.2
2.00	1.4	1035.0	-4.176	41.0	165.5	0.079	1469.9	-0.285	68.3
2.50	1.6	900.0	-4.446	55.5	219.0	0.117	1468.0	-0.303	90.4
3.00	1.7	830.0	-4.586	65.0	251.1	0.148	1466.0	-0.322	103.6
4.00	2.0	742.0	-4.762	78.5	291.0	0.203	1463.2	-0.351	120.1
6.25	2.5	640.0	-4.966	94.9	345.1	0.259	1459.0	-0.389	142.4
9.00	3.0	575.0	-5.096	113.9	400.8	0.337	1453.8	-0.438	165.4
12.00	3.5	535.0	-5.176	129.3	447.0	0.399	1445.5	-0.517	184.5
27.00	5.2	487.5	-5.271	135.2	467.7	0.417	1441.0	-0.559	193.0
67.00	8.2	456.0	-5.334	157.0	509.0	0.552	1435.9	-0.608	210.1
135.00	11.6	441.0	-5.362	175.3	553.0	0.647	1429.2	-0.671	228.2
1894.00	32.9	410.0	-5.426	194.0	593.0	0.754	1423.0	-0.730	244.7
				214.3	638.2	0.867	1413.0	-0.825	263.4
stopped overnight at 1.03 mm				238.0	675.0	1.030	1406.0	-0.891	278.6
restarted at 1.136 mm				238.0	622.0	1.136	1390.0	-1.043	256.7
				238.0	622.0	1.136	1390.0	-1.043	256.7
				253.0	678.5	1.173	1387.0	-1.071	280.0
				263.0	714.0	1.202	1387.0	-1.071	294.7
				287.0	759.0	1.360	1383.6	-1.103	313.2
				314.3	788.0	1.567	1373.4	-1.200	325.2
				342.0	813.0	1.794	1365.5	-1.275	335.5
				364.0	821.2	1.998	1356.5	-1.360	338.9
				377.0	824.8	2.120	1349.5	-1.427	340.4
				399.0	834.0	2.322	1341.0	-1.507	344.2
				413.0	839.3	2.451	1335.5	-1.559	346.4
				434.2	844.4	2.653	1328.0	-1.630	348.5
				464.0	849.5	2.941	1318.9	-1.717	350.6
				475.0	846.0	3.054	1310.0	-1.750	350.0
				494.0	848.2	3.244	1307.0	-1.829	350.1
				524.7	850.5	3.346	1303.0	-1.867	351.0

CYCLE A

86-25-23

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS	SAMPLE DIMENSIONS		Proving	Consol	Normal		
BOREHOLE NUMBER	85-3-2				Ring	Height	Stress		
SAMPLE NUMBER	11	length,mm	59.50		A	0.149	27.31	227.3	
SAMPLE DEPTH, m	12.4-12.6	width,mm	59.50	AREA,mm ²	3540.25	B	0.149	21.88	498.1
TEST DATE	86-03-10	height,mm	25.20	VOLUME,cc	89.27	C	0.308	22.38	750.0

Time (min)	Square Root of Time /(min)	Normal Dial .002mm	Normal Displ. (mm)	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. (mm)	Normal Dial .002mm	Volume Strain (%)	Shear stress (kPa)
0.00	0.0	2400.0	0	0.0	0.0	0.000	2061.0	0.000	0.0
0.50	0.7	2000.0	-0.800	1.0	16.1	-0.022	2061.0	0.000	6.6
1.50	1.2	1574.0	-1.652	5.9	24.9	0.009	2061.0	0.000	10.3
2.00	1.4	1546.0	-1.708	12.5	32.4	0.060	2059.9	-0.018	13.4
2.50	1.6	1532.0	-1.736	26.3	46.3	0.170	2045.5	-0.133	19.1
3.00	1.7	1527.0	-1.746	36.6	55.0	0.256	2036.8	-0.200	22.7
4.00	2.0	1527.0	-1.746	48.1	63.0	0.355	2029.0	-0.275	26.0
5.50	2.3	1526.0	-1.748	61.0	70.9	0.468	2019.0	-0.360	29.3
71.00	8.4	1473.0	-1.854	74.0	77.5	0.585	2011.0	-0.429	32.0
1021.00	32.0	1456.2	-1.868	88.0	83.0	0.714	2001.5	-0.510	34.0
				105.0	88.0	0.873	1995.9	-0.559	36.4
stopped overnight at 2.095 mm				121.1	93.7	1.024	1984.0	-0.654	38.7
restart at 2.124 mm				134.9	96.3	1.155	1979.0	-0.704	39.7
				153.0	99.9	1.330	1970.9	-0.773	41.2
				175.0	102.7	1.545	1960.1	-0.797	42.4
				189.9	105.0	1.687	1950.9	-0.876	43.7
				211.2	107.6	1.897	1954.0	-0.918	44.4
				231.5	109.8	2.095	1945.4	-0.992	45.0
				252.0	98.0	2.124	1937.0	-1.064	46.4
				245.0	113.0	2.224	1935.0	-1.081	46.6
				257.5	113.2	2.329	1934.0	-1.090	46.7
				277.2	114.9	2.542	1929.4	-1.129	47.4
				306.5	115.9	2.833	1925.0	-1.167	47.8
				333.0	116.6	3.097	1920.0	-1.210	48.1
				350.5	117.0	3.271	1917.4	-1.232	48.3
				363.1	117.9	3.395	1910.2	-1.294	48.7
				382.5	118.0	3.589	1910.0	-1.296	48.7
				397.6	118.1	3.740	1909.0	-1.304	48.7
				418.5	118.3	3.948	1904.0	-1.347	48.8
peak shear stress at 48.9 kPa				445.1	118.5	4.214	1901.1	-1.372	48.9
				457.2	118.5	4.335	1900.0	-1.381	48.9
				472.4	118.5	4.487	1895.0	-1.420	48.9
end of peak run				485.7	118.9	4.619	1895.1	-1.420	49.1
residual shear stress, by hand (r1)				975.7	97.0	9.563	1780.0	-3.411	43.2
			(r2)	1955.7	91.0	19.375	1700.0	-3.097	37.6
			(r3)	2935.7	81.0	29.195	1582.0	-4.110	33.4
			(r4)	3915.7	77.0	39.003	1521.0	-4.633	31.8
			(r5)	4695.7	72.0	48.813	1475.0	-5.020	29.7
			(r6)	5875.7	71.0	58.615	1434.0	-5.380	29.3
residual shear stress,			(r7)	6365.7	0	63.657	1396.0	-5.689	0.0
machine speed at 0.5 %/hr				6383.7	27.9	63.781	1364.3	-5.978	11.5
				6426.7	62.1	64.143	1331.0	-6.263	25.6
				6463.2	78.9	64.474	1314.2	-6.408	32.6

CYCLE A

86-25-26

DIRECT SHEAR TESTS

PROJECT NUMBER		BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER						Ring	Height	Stress
SAMPLE NUMBER	11	length,mm	59.50	A	0.149	23.31	227.3	
SAMPLE DEPTH,m	12.4-12.6	width,mm	59.50	AREA,mm ²	3540.25	0.149	21.38	498.1
TEST DATE	86-03-10	height,mm	25.20	VOLUME,cc	89.27	0.308	22.38	750.0

Time	Square	Normal	Normal	Horiz	P.Ring	Horiz.	Normal	Volume	Shear
(min)	Root of	Dial	Displ.	Dial	Dial	Displ.	Dial	Strain	stress
	Time	.002mm	(mm)	.01mm	.002mm	(mm)	.002mm	(%)	(kPa)
	/(min)								

6492.7	89.8	64.747	1312.0	-6.426	37.1
6536.7	102.0	65.163	1304.0	-6.495	42.1
6561.7	107.5	65.402	1299.0	-6.538	44.4
6574.7	109.5	65.528	1297.5	-6.551	45.2
7037.7	104.0	70.169	1295.0	-6.572	42.9

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS	Proving	Consol	Normal
BOREHOLE NUMBER	85-3-2				Ring	Height	Stress
SAMPLE NUMBER	11	length,mm	59.50		A	0.149	23.31
SAMPLE DEPTH,m	12.4-12.6	width,mm	59.50	AREA,mm ²	3548.25	B	0.149
TEST DATE	86-03-18	height,mm	25.20	VOLUME,cc	89.27	C	0.308

Time (min)	Square Root of Time (min)	Normal Dial .002mm	Normal Displ. (mm)	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. (mm)	Normal Dial .002mm	Volume Strain (%)	Shear stress (kPa)
2.00	0.0	3272.0	0.000	0.0	0.0	0.000	2100.0	0.000	0.0
0.25	0.5	3130.0	-0.204	3.0	4.1	0.022	2093.0	-0.064	1.7
0.50	0.7	2140.0	-2.264	18.9	61.5	0.366	2084.0	-0.146	25.4
1.00	1.0	2002.0	-2.540	22.0	64.0	0.092	2082.0	-0.165	26.4
1.50	1.2	1950.0	-2.644	41.0	114.0	0.182	2080.9	-0.339	47.0
2.00	1.4	1919.0	-2.706	56.4	157.7	0.249	2058.0	-0.384	65.1
2.50	1.6	1896.0	-2.752	67.5	178.9	0.317	2048.0	-0.419	72.8
3.00	1.7	1871.0	-2.802	95.0	236.5	0.477	2031.0	-0.601	97.6
3.50	1.9	1852.0	-2.840	119.5	268.5	0.658	2020.0	-0.841	110.0
4.00	2.0	1834.0	-2.876	138.0	305.0	0.770	1997.0	-0.934	125.0
4.50	2.1	1815.0	-2.914	158.3	324.0	0.935	1984.0	-1.000	130.7
5.00	2.2	1806.0	-2.932	177.2	347.0	1.079	1973.0	-1.101	143.2
6.00	2.4	1785.0	-2.974	193.8	376.0	1.186	1967.5	-1.211	155.2
7.00	2.6	1768.0	-3.000	204.0	384.0	1.278	1962.2	-1.278	158.0
8.00	2.8	1753.0	-3.038	235.0	415.0	1.520	1947.3	-1.432	171.3
19.00	4.4	1686.0	-3.172	237.0	409.0	1.552	1935.5	-1.504	160.0
979.00	31.3	1612.0	-3.320	248.0	371.0	1.730	1901.0	-1.819	157.1
stopped weekend at 1.552 am				256.0	398.0	1.764	1902.0	-1.810	164.0
restart at 1.738 am				272.5	457.5	1.810	1902.0	-1.810	180.0
				274.0	449.5	1.849	1902.0	-1.810	185.5
				294.5	466.2	2.013	1890.0	-1.846	192.4
				303.5	481.0	2.073	1895.0	-1.874	198.5
				314.0	467.5	2.205	1890.0	-1.920	192.9
				443.0	503.5	3.423	1881.0	-2.002	207.0
				463.0	514.0	3.610	1876.0	-2.048	212.1
				477.5	511.0	3.751	1860.0	-2.121	211.2
				467.0	521.4	3.627	1861.0	-2.185	215.2
				517.5	531.9	4.111	1855.0	-2.239	219.5
				557.0	544.5	4.401	1845.0	-2.331	224.7
				575.0	545.6	4.659	1841.0	-2.367	225.2
stopped overnight at 4.005 am				594.5	547.5	4.850	1840.0	-2.377	226.0
restart at 3.003 am				614.5	519.0	4.500	1835.0	-2.422	219.0
				615.0	543.4	5.063	1832.0	-2.460	224.3
				620.5	572.1	5.000	1829.0	-2.477	226.1
				636.0	550.0	5.258	1828.0	-2.486	227.3
				657.0	560.2	5.450	1827.3	-2.493	231.2
				677.5	563.5	5.640	1825.9	-2.505	232.6
				697.5	564.0	5.840	1822.0	-2.534	233.1
				747.1	566.0	6.209	1819.0	-2.569	241.0
				750.0	569.4	6.661	1815.0	-2.605	235.0
				918.0	574.0	7.032	1813.5	-2.619	236.9
peak shear stress at 242.5 kPa				846.0	587.0	7.204	1809.9	-2.652	242.6
				879.0	575.0	7.640	1800.0	-2.669	237.3

CYCLE 8

96-25-08

DIRECT SHEAR TESTS

PROJECT NUMBER	951-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER	85-3-2					Ring	Height	Stress
SAMPLE NUMBER	11	length,mm	59.50			A	0.149	227.3
SAMPLE DEPTH,m	12.4-12.6	width,mm	59.50	AREA,mm ²	3540.25	B	0.149	498.1
TEST DATE	86-03-10	height,mm	25.20	VOLUME,cc	89.27	C	0.308	752.0

Time (min)	Square Root of Time / (min)	Normal Dial .002mm	Normal Displ. (mm)	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. (mm)	Normal Dial .002mm	Volume Strain (%)	Shear stress (kPa)
end of peak run				880.0	569.0	7.662	1808.0	-2.669	234.0
residual shear stress, by hand (r1)				2640.0	330.0	25.740	1651.0	-4.184	136.2
(r2)				4400.0	303.0	43.394	1532.0	-5.192	129.1
(r3)				6160.0	370.0	60.860	1433.0	-6.897	152.7
(r4)				7920.0	323.0	78.554	1360.0	-8.764	133.0
(r5)				9680.0	360.0	96.080	1300.0	-7.313	148.6
residual shear stress, (r6)				10170.0	0	101.700	1246.0	-7.906	0.0
machine speed at 0.5 %/hr				10570.0	16.0	105.748	1185.0	-8.764	6.6
				10615.0	49.5	106.051	1175.0	-8.455	20.4
				10654.5	158.0	106.229	1159.0	-8.801	65.2
				10692.0	238.5	106.443	1135.0	-9.821	92.4
				10732.5	310.0	106.705	1122.4	-8.936	127.9
				10778.5	393.0	106.999	1110.0	-9.049	162.2
				11006.5	503.5	112.058	1075.0	-9.769	207.0

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER	85-3-2					Ring	Height	Stress
SAMPLE NUMBER	11	length,mm	59.52		A	0.149	23.31	227.2
SAMPLE DEPTH,mm	12.4-12.6	width,mm	59.52	AREA,mm ²	3540.25	0.149	21.88	498.1
TEST DATE	96-03-10	height,mm	25.28	VOLUME,cc	89.27	0.308	22.38	758.2

Time (min)	Square Root of Time /(min)	Normal Dial Displ. .002mm	Normal Displ. (mm)	Horiz Dial Displ. .01mm	P.Ring Dial Displ. .002mm	Horiz. Displ. (mm)	Normal Dial Displ. .002mm	Volume Strain (%)	Shear stress (kPa)	
0.00	0.0	3491.0	0.000	0.0	0.0	0.000	1986.0	0.000	0.0	
0.16	0.4	3180.0	-0.622	6.5	14.8	0.035	1989.0	0.027	12.6	
0.25	0.5	3010.0	-0.962	16.2	29.9	0.082	1995.0	-0.299	34.3	
0.50	0.7	2650.0	-1.682	24.4	40.5	0.163	1997.0	-0.170	34.5	
1.00	1.0	2520.0	-1.942	36.5	89.7	0.166	1973.0	-0.295	76.5	
2.50	1.6	2470.0	-2.042	47.5	94.2	0.287	1865.0	-0.366	80.4	
3.00	1.7	2430.0	-2.122	59.2	138.0	0.316	1854.0	-0.465	117.7	
3.50	1.9	2411.0	-2.160	85.0	182.5	0.485	1837.0	-0.617	155.7	
4.00	2.0	2387.0	-2.228	104.5	210.8	0.623	1827.0	-0.706	179.8	
111.20	10.5	2127.5	-2.727	119.5	229.5	0.736	1816.0	-0.786	195.8	
4254.00	65.7	2079.0	-2.824	137.0	250.2	0.870	1806.0	-0.894	213.4	
				157.2	268.0	1.006	1797.0	-0.974	226.6	
				193.5	294.0	1.347	1785.0	-1.061	250.8	
				210.0	303.5	1.493	1778.0	-1.144	258.9	
stopped weekend at 1.708 mm				228.5	312.9	1.659	1770.0	-1.215	266.9	
restart at 1.797 mm				228.5	309.5	1.708	1762.0	-1.287	246.1	
				245.5	329.8	1.797	1760.0	-1.305	260.5	
				252.0	330.1	1.860	1756.0	-1.340	261.6	
				265.0	332.0	1.906	1753.0	-1.367	263.2	
				285.0	336.1	2.178	1745.0	-1.439	286.7	
				307.0	341.0	2.348	1739.0	-1.492	298.9	
				322.7	346.3	2.524	1734.0	-1.537	295.4	
				368.1	357.0	2.967	1720.0	-1.662	304.6	
				400.0	362.0	3.284	1705.0	-1.792	309.8	
				431.0	365.0	3.588	1695.1	-1.885	311.4	
peak shear stress at 315.6 kPa				464.1	368.0	3.985	1689.0	-1.939	317.8	
end of peak run				497.0	370.0	4.230	1685.0	-1.975	315.6	
residual shear stress , by hand (r1)				1491.0	243.0	14.424	1605.0	-2.511	207.3	
				(r2)	2495.0	203.0	24.444	1589.0	-2.833	173.2
				(r3)	3479.0	198.0	34.410	1572.0	-2.985	162.1
				(r4)	4473.0	198.0	44.350	1553.0	-3.155	162.1
				(r5)	5467.0	185.0	54.284	1533.0	-3.313	162.1
residual shear stress ,				(r6)	5964.0	0	59.640	1511.0	-3.520	0.0
machine speed at 2.5 %/hr					5982.0	40.0	59.720	1440.0	-4.164	34.1
					6012.0	115.0	59.890	1428.0	-4.272	56.1
					6053.0	183.0	60.164	1407.0	-4.459	156.1
					6086.5	224.0	60.417	1391.0	-4.602	191.1
					6127.9	265.0	60.746	1380.0	-4.781	226.1
					6172.0	296.0	61.128	1367.0	-4.917	252.5
					6225.0	346.0	61.958	1353.0	-4.942	295.2

CYCLE A

86-25-09

DIRECT SHEAR TESTS

```

=====
PROJECT NUMBER  951-1298   BOX DIMENSIONS   SAMPLE DIMENSIONS   Proving   Consol   Normal
BOREHOLE NUMBER 85-3-2                                Ring   Height   Stress
SAMPLE NUMBER   19         length,mm   59.50                A    0.308   24.54   148.4
SAMPLE DEPTH,m  24.4-25.0       width,mm   59.50   AREA,mm^2 3540.25 B    0.308   20.96   299.6
TEST DATE       86-03-26   height,mm  25.20   VOLUME,cc  89.27 C    0.149   19.14   598.9
=====

```

```

=====
Time   Square   Normal   Normal   Horiz   P.Ring   Horiz.   Normal   Volume   Shear
min    Root of    Dial    Displ.   Dial    Dial     Displ.   Dial    Strain   stress
      / min   .002mm   mm       .01mm   .002mm   mm       .002mm   %       kPa
=====
0.00    0.0   1350.0    0    0.0    0.0    0.000   2150.0    0.000    0.0
0.25    0.5   1335.0   -0.030  6.0    5.8    0.048   2147.0   -0.024    4.9
1.00    1.0   1330.0   -0.040  19.5   21.0   0.153   2138.0   -0.097   17.9
1.50    1.2   1325.0   -0.050  40.0   36.1   0.328   2119.8   -0.245   30.9
2.00    1.4   1321.0   -0.058  62.0   47.0   0.526   2117.8   -0.261   40.1
3.00    1.7   1301.0   -0.098  89.2   55.0   0.782   2102.0   -0.390   46.9
60.00    7.7   1190.0   -0.320  106.0  58.8   0.942   2095.0   -0.446   50.2
96.00    9.3   1187.0   -0.326  134.0  62.3   1.215   2086.0   -0.519   53.1
1120.00  33.5   1170.0   -0.360  154.8  64.5   1.419   2080.0   -0.568   55.0
        176.5  65.1   1.635   2076.2   -0.599   55.5
        198.0  66.0   1.848   2074.0   -0.617   56.3
        214.5  66.7   2.012   2071.5   -0.637   56.9
stopped weekend at 2.228 mm
restarted at 2.248 mm
peak shear stress at 57.4 kPa
        236.0  66.1   2.228   2070.0   -0.649   56.4
        236.0  66.0   2.248   2065.0   -0.690   47.8
        245.0  67.3   2.315   2063.0   -0.706   57.4
        259.9  67.3   2.464   2061.0   -0.722   57.4
        275.0  66.9   2.616   2061.0   -0.722   57.1
        287.2  66.2   2.740   2060.4   -0.727   56.5
        311.5  65.5   2.984   2060.0   -0.730   55.9
        344.0  64.5   3.311   2060.0   -0.730   55.0
        367.1  63.6   3.544   2058.5   -0.743   54.3
        405.0  62.4   3.925   2058.0   -0.747   53.2
        431.5  61.9   4.191   2057.9   -0.748   52.8
        449.5  61.1   4.373   2057.5   -0.751   52.1
end of peak run
        476.0  60.1   4.640   2057.4   -0.752   51.3
residual shear stress, by hand (r1) 1428.0  48.0  14.184  1976.0   -1.412  40.9
                                   (r2) 2380.0  41.0  23.718  1930.0   -1.786  35.0
                                   (r3) 3332.0  39.0  33.242  1869.0   -2.118  33.3
                                   (r4) 4284.0  37.0  42.766  1864.0   -2.321  31.6
                                   (r5) 5236.0  32.0  52.296  1841.0   -2.508  27.3
residual shear stress, (r6) 5712.0  0.0  57.120  1841.2   -2.508  0.0
machine speed at 0.5 1/hr.
        5718.5  10.0  57.145  1840.5   -2.512  0.5
        5757.0  40.2  57.490  1818.0   -2.695  34.3
        5823.0  67.3  58.093  1827.2   -2.784  54.2
        5852.0  69.0  58.392  1807.0   -2.794  58.9
        5893.0  71.0  58.788  1805.0   -2.820  60.6
        6352.0  71.0  63.378  1802.0   -2.825  60.6
        6373.0  71.2  63.588  1801.5   -2.829  60.7
        6389.0  71.2  63.738  1801.5   -2.829  60.7
=====

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CYCLE 8

85-25-27

DIRECT SHEAR TESTS

```

=====
PROJECT NUMBER  951-1298   BOX DIMENSIONS
BOREHOLE NUMBER 95-3-2
SAMPLE NUMBER    19      length,mm  59.50
SAMPLE DEPTH,mm  24.4-25.0 width,mm  59.50  AREA,mm 2  3540.25  B  3.728  20.96  299.6
TEST DATE       96-03-26 height,mm  25.20  VOLUME,cc  89.27  C  0.149  19.14  598.9
=====

```

```

=====
Time   Square   Normal   Normal   Horiz   P.Ring   Horiz.   Normal   Volume   Shear
min    Root of    Dial     Displ.   Dial    Dial     Displ.   Dial     Strain   stress
      / min      .002mm   mm       .01mm   .002mm   mm       .002mm   %        kPa
=====
0.00    0.0    2338.0    0.000    0.0     0.0     0.000    2274.0    0.000    0.0
1.00    1.0    960.0    -2.756    13.0    26.8    0.076    2258.0    -0.153    22.9
1.25    1.1    850.0    -2.976    13.0    26.8    0.084    2222.0    -0.496    22.9
1.50    1.2    810.0    -3.056    28.5    53.8    0.179    2218.0    -0.574    45.2
2.00    1.4    764.0    -3.148    43.5    69.5    0.296    2216.0    -0.551    59.0
3.00    1.7    690.0    -3.296    64.5    84.2    0.477    2198.0    -0.725    71.8
4.00    2.0    613.0    -3.450    78.0    92.2    0.596    2190.0    -0.801    79.7
5.00    2.2    576.0    -3.524    90.0    97.2    0.706    2182.0    -0.878    82.9
10.00   3.2    442.0    -3.792    104.5   103.0    0.839    2175.0    -0.945    87.9
27.00   5.2    375.0    -3.926    137.0   113.9    1.142    2160.0    -1.068    97.2
110.00  10.5   346.0    -3.984    157.2   119.0    1.334    2151.0    -1.174    101.5
210.00  14.8   338.0    -4.000    170.0   123.0    1.534    2143.0    -1.250    104.9
305.00  17.5   333.9    -4.008    196.5   125.1    1.715    2130.0    -1.298    106.7
1253.00 35.4   319.0    -4.038    215.0   127.4    1.895    2131.0    -1.364    108.7
                                232.1    129.4    2.062    2127.0    -1.403    110.4
stopped weekend at 2.297 mm      256.0    131.4    2.297    2119.0    -1.479    112.1
restarted at 2.317 mm          256.5    124.0    2.317    2115.0    -1.517    105.8
                                265.0    133.1    2.384    2106.0    -1.584    113.5
                                296.5    134.5    2.716    2102.0    -1.641    114.7
                                326.5    134.5    2.996    2094.0    -1.718    114.7
                                361.5    135.4    3.344    2085.0    -1.803    115.5
                                398.5    136.0    3.713    2076.0    -1.889    116.0
peak shear stress at 116.2 kPa  435.0    136.2    4.078    2068.0    -1.985    116.2
                                450.5    136.2    4.233    2064.0    -2.004    116.2
                                491.5    135.4    4.644    2058.0    -2.061    115.5
stopped overnight at 4.800 mm   507.0    135.0    4.800    2056.0    -2.061    115.2
restarted at 4.822 mm          527.2    125.2    4.822    2051.0    -2.128    106.8
                                529.5    135.4    5.024    2047.0    -2.166    115.5
                                556.5    134.5    5.296    2044.0    -2.195    114.7
                                586.5    134.5    5.596    2040.0    -2.204    114.7
end of peak run                616.7    134.5    5.898    2040.0    -2.233    114.7
residual shear stress, by hand (r1) 1552.4    60  16.768    1940.0    -3.193    58.2
                                (r2) 2064.4    67  20.710    1817.0    -4.261    57.2
                                (r3) 4018.4    60  40.264    1755.0    -4.952    51.2
                                (r4) 5552.4    60  55.404    1710.0    -5.182    51.2
                                (r5) 6786.4    60  67.744    1672.0    -5.744    51.2
residual shear stress,         (r6) 7403.4    0  74.034    1667.0    -5.792    3.0
machine speed at 0.5 1/hr.     7424.9    34.3  74.179    1655.0    -5.926    29.7
                                7461.9    74.5  74.470    1627.0    -6.174    63.6
                                7485.9    91.8  74.675    1618.0    -6.260    78.0
                                7535.9    104  74.851    1610.0    -6.336    88.7
                                7676.4    139  79.526    1595.0    -6.574    118.6
                                8037.9    139  80.101    1585.0    -6.574    118.6
=====

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CYCLE 8

32-05-09

DIRECT SHEAR TESTS

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=====
PROJECT NUMBER  851-1298   BOX DIMENSIONS   SAMPLE DIMENSIONS   Proving   Consol   Normal
BOREHOLE NUMBER 85-3-2                                Ring   Height   Stress
SAMPLE NUMBER   19      length,mm      59.50                A    0.308   24.64   148.4
SAMPLE DEPTH,m  24.4-25.0 width,mm      59.50      AREA,mm^2 3540.25 B    0.308   20.96   299.6
TEST DATE       86-03-26 height,mm,    25.20      VOLUME,cc  89.27 C    0.149   19.14   598.9
=====

```

```

=====
Time   Square   Normal   Normal   Horiz   P.Ring   Horiz.   Normal   Volume   Shear
min    Root of    Dial    Displ.   Dial    Dial     Displ.   Dial    Strain   stress
      Time   .002mm   mm      .01mm   .002mm   mm      .002mm   %      kPa
      / min
=====

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8186.4      139   80.786   1584.0   -6.584   118.6
8172.9      139   81.251   1584.0   -6.584   118.6
8202.4      134   81.756   1584.0   -6.584   114.3

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DIRECT SHEAR TESTS

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=====
PROJECT NUMBER  851-1298      BOX DIMENSIONS      SAMPLE DIMENSIONS      Proving   Consol   Normal
BOREHOLE NUMBER 85-3-2
SAMPLE NUMBER    19      length,mm      59.58      A      0.308      24.64      146.4
SAMPLE DEPTH,m   24.4-25.2 width,mm      59.58      AREA,mm^2  7540.25  B      0.308      20.96      299.6
TEST DATE        26-03-76 height,mm     25.28      VOLUME,cc   89.27  C      0.149      19.14      598.9
=====

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=====
Time   Square   Normal   Normal   Horiz   P.Ring   Horiz.   Normal   Volume   Shear
min    Root of    Dial    Displ.   Dial    Dial     Displ.   Dial    Strain    stress
      / min
=====
0.00    0.0    7000.0    0.000    0.0     0.0     0.000    2455.0    0.000    0.0
0.50    0.7    1150.0   -4.300    9.0     10.0    0.070    2453.0    -0.001    4.1
1.00    1.0    1052.0   -4.496    25.0    74.2    0.102    2442.0    -0.176    72.6
1.50    1.2    978.0    -4.644    45.5    146.5    0.162    2438.0    -0.170    80.5
2.00    1.4    922.0    -4.756    77.0    206.0    0.258    2431.0    -0.251    85.0
2.50    1.6    852.0    -4.900    99.0    282.5    0.425    2425.0    -0.313    116.6
3.00    1.7    825.0    -4.950    114.0    314.0    0.520    2420.0    -0.366    129.6
30.00   9.5    375.0    -5.930    141.0    349.0    0.712    2414.0    -0.420    144.0
1259.00 32.5    268.5    -6.063    161.0    372.0    0.864    2407.0    -0.478    153.9
                                182.0    397.0    1.034    2402.0    -0.554    162.2
                                205.0    422.0    1.206    2398.0    -0.596    174.2
                                221.0    438.0    1.350    2394.0    -0.637    177.5
stopped weekend at 1.545 mm
restarted at 1.616 mm
                                244.0    448.5    1.545    2390.0    -0.679    185.1
                                245.0    416.9    1.616    2376.0    -0.825    170.1
                                256.0    449.1    1.670    2373.0    -0.857    185.3
                                271.5    482.8    1.749    2373.0    -0.857    199.3
                                284.0    485.4    1.869    2372.0    -0.867    208.3
                                297.8    479.1    2.020    2369.0    -0.899    197.7
                                321.0    488.2    2.234    2362.0    -0.929    201.5
                                357.0    498.1    2.574    2345.0    -1.149    205.6
                                368.3    505.6    2.792    2340.0    -1.202    208.7
                                420.9    512.0    3.185    2327.5    -1.332    211.3
                                454.1    523.0    3.495    2317.0    -1.434    215.8
                                475.0    529.0    3.698    2316.0    -1.452    217.0
stopped overnight at 3.965 mm
restarted at 3.959 mm
                                501.0    522.5    3.965    2307.0    -1.543    215.6
                                501.0    510.3    3.989    2301.0    -1.606    210.6
                                504.0    505.9    4.036    2298.0    -1.640    208.0
                                524.0    520.0    4.184    2297.5    -1.646    217.9
                                545.2    529.0    4.394    2295.1    -1.671    218.3
                                564.5    528.0    4.589    2290.0    -1.722    217.0
                                584.5    528.0    4.789    2287.9    -1.746    217.8
peak shear stress at 210.0 kPa
                                623.0    533.0    4.964    2283.0    -1.787    220.0
                                625.0    524.0    5.202    2250.0    -1.829    216.7
                                665.0    523.0    5.604    2269.0    -1.944    218.6
                                697.0    523.7    5.923    2266.5    -1.970    216.1
end of peak run
                                724.5    515.0    6.215    2265.0    -1.985    212.5
residual shear stress, by hand (r1) 2173.0    220.0    21.290    2126.0    -2.438    90.0
                                (r2) 3621.0    272.0    35.670    2052.0    -4.211    111.4
                                (r3) 5069.0    268.0    50.154    1992.0    -4.808    110.6
                                (r4) 6517.0    257.0    64.656    1949.0    -5.297    106.1
                                (r5) 7965.0    273.0    79.104    1909.0    -5.716    112.7
residual shear stress,
                                (r6) 8689.0    0.0    86.890    1908.0    -5.716    0.0
machine speed at 0.5 1/hr.
                                9125.0    500.0    90.234    1887.0    -5.975    209.7
=====

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CYCLE C

86-05-09

DIRECT SHEAR TESTS

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=====
PROJECT NUMBER  851-1298    BOX DIMENSIONS    SAMPLE DIMENSIONS    Proving    Consol    Normal
BOREHOLE NUMBER 85-3-2                                     Ring    Height    Stress
SAMPLE NUMBER   19    length,mm    59.50    A    0.308    24.64    148.4
SAMPLE DEPTH,m  24.4-25.0    width,mm    59.50    AREA,mm^2    3540.25    B    0.308    20.96    299.6
TEST DATE       86-03-26    height,mm,    25.20    VOLUME,cc    89.27    C    0.149    19.14    598.9
=====

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```

=====
Time   Square    Normal    Normal    Horiz    P.Ring    Horiz.    Normal    Volume    Shear
min   Root of      Dial    Displ.    Dial    Dial    Displ.    Dial    Strain    stress
      Time      .002mm    mm    .01mm    .002mm    mm    .002mm    %    kPa
      / min
=====
          9147.0    501.3    90.467    1886.2    -5.944    206.9
          9166.0    501.3    90.657    1886.0    -5.946    206.9
          9200.0    491.5    91.897    1886.0    -5.946    202.8
          9230.5    493.0    91.319    1886.0    -5.946    203.5
          9190.5    490.0    90.925    1885.0    -5.956    202.2
          9250.8    487.5    91.533    1884.0    -5.967    201.2
          9271.5    481.8    91.751    1883.0    -5.977    198.8
          9290.0    481.5    91.937    1883.0    -5.977    198.7
=====

```

CYCLE A

85-05-27

DIRECT SHEAR TESTS

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=====
PROJECT NUMBER  851-1298  BOX DIMENSIONS  SAMPLE DIMENSIONS  Proving  Consol  Normal
BOREHOLE NUMBER 95-10-2                                     Ring  Height  Stress
SAMPLE NUMBER    7      length,mm    59.50      A    0.308    21.32    299.6
SAMPLE DEPTH,mm  5.0-6.0 width,mm    59.50  AREA,mm^2  3540.25  3    0.149    20.01    598.7
TEST DATE        86-04-08 height,mm, (H1) 25.20  VOLUME,cc  89.27  0    0.149    17.70    999.5
=====

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```

=====
Time   Square   Normal   Normal   Horiz   P.Ring   Horiz.   Normal   Volume   Shear
min    Root of    Dial    Displ.   Dial    Dial     Displ.   Dial    Strain    stress
      / min                                     .002mm   mm      .002mm   %      kPa
=====
0.00    0.0    2470.0    0        0.0      0.0     0.000    2306.0    0.000    0.0
0.33    0.6    1400.0   -2.060    14.0     30.0     0.050    2274.0   -0.300    25.6
0.58    0.8    1220.0   -2.420    43.0     66.5     0.097    2240.0   -0.619    56.7
0.75    0.9    1150.0   -2.560    54.5     77.5     0.090    2230.0   -0.713    66.1
1.00    1.0    1075.0   -2.710    75.0     93.0     0.064    2214.0   -0.863    79.3
2.00    1.4    933.0    -2.994    105.0    111.4     0.027    2192.0   -1.069    95.0
3.00    1.7    850.0    -3.144    136.0    126.0     1.128    2174.0   -1.238    107.5
9.00    3.0    652.0    -3.556    174.0    139.2     1.462    2157.0   -1.398    118.8
25.00   5.0    559.0    -3.742    193.5    143.9     1.647    2150.0   -1.463    122.8
50.00   7.7    532.0    -3.796    214.5    148.5     1.849    2162.0   -1.351    126.7
170.00  13.0    510.0    -3.824    391.0    163.0     3.584    2107.0   -1.867    139.1
329.00  18.1    515.0    -3.830    608.0    162.8     6.554    2080.0   -2.120    138.9
4217.00 64.9    492.0    -3.876    713.0    162.5     6.805    2077.0   -2.148    138.6
peak shear stress at 139.1 kPa      742.0    162.4     7.095    2075.0   -2.167    138.5
end of peak run                    777.0    162.2     7.446    2074.0   -2.176    138.4
residual shear stress, by hand (r1) 2331.0    135.0    23.040    1940.0   -3.433    115.2
                                   (r2) 3885.0    112.0    38.626    1791.0   -4.631    95.5
                                   (r3) 5439.0     95.0    54.200    1795.0   -4.794    81.2
                                   (r4) 6993.0     89.0    69.752    1659.0   -6.069    75.9
                                   (r5) 8547.0     85.0    85.300    1618.0   -6.454    72.5
residual shear stress, (r6) 9324.6     0.0    93.240    1611.0   -6.520     0.0
machine speed at 0.5 %/hr.        9334.0     29.0    93.282    1527.0   -7.328    24.7
                                   9380.8     84.0    93.640    1496.0   -7.598    71.7
                                   9406.5    102.0    93.861    1464.0   -7.711    87.0
                                   9863.7    159.5    98.318    1450.0   -8.032    136.1
                                   9904.5    159.5    98.726    1449.0   -8.039    136.1
                                   9957.0    159.4    99.251    1440.0   -8.249    136.0
                                   10015.0   159.2    99.632    1446.0   -8.266    135.8
                                   10031.0   159.0   100.492    1444.0   -8.086    135.6
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CYCLE 8

86-25-29

DIRECT SHEAR TESTS

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PROJECT NUMBER  851-1298  BOX DIMENSIONS  SAMPLE DIMENSIONS  Proving  Consol  Normal
BOREHOLE NUMBER 85-10-2
SAMPLE NUMBER   7        length,mm  59.52  A  0.300  21.32  299.6
SAMPLE DEPTH,cm 5.0-6.0  width,mm  59.52  AREA,mm^2  3540.25  B  0.149  20.01  598.9
TEST DATE      86-04-28  height,mm, (H1)  25.20  VOLUME,cc  89.27  C  0.149  17.90  999.5
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Time  Square  Normal  Normal  Horiz  P.Ring  Horiz.  Normal  Volume  Shear
min  Root of  Dial  Displ.  Dial  Dial  Displ.  Dial  Strain  stress
      Time  .002mm  mm  .01mm  .002mm  mm  .002mm  %  kPa
      / min
=====
0.00  0.0  5279.0  0.000  2.0  0.0  0.000  3099.0  0.000  0.0
0.50  0.7  3900.0  -2.678  22.0  13.5  0.193  3089.0  -0.100  5.6
1.00  1.0  3650.0  -3.178  54.0  94.2  0.377  3075.0  -0.240  24.7
1.50  1.2  3536.0  -3.406  68.5  132.5  0.420  3075.0  -0.240  54.7
2.00  1.4  3422.0  -3.634  80.5  195.5  0.414  3067.0  -0.320  60.7
3.00  1.7  3333.0  -3.812  113.9  248.5  0.642  3051.0  -0.400  102.6
5.00  2.2  3165.0  -4.148  150.6  320.0  0.866  3031.0  -0.600  132.1
9.00  3.0  2960.0  -4.550  189.8  382.9  1.132  3010.0  -0.890  158.0
25.00  5.0  2749.0  -4.960  209.0  410.5  1.269  2999.0  -0.999  169.4
56.00  7.5  2712.0  -5.054  238.0  440.0  1.500  2988.0  -1.100  181.6
165.00  12.0  2689.0  -5.100  410.0  505.0  3.090  2905.0  -1.930  208.4
224.00  18.0  2678.0  -5.122  732.0  565.0  6.190  2815.0  -2.830  233.2
4213.00  64.9  2642.0  -5.194  756.0  569.0  6.422  2810.0  -2.680  234.6
                               791.5  563.0  6.789  2802.0  -2.960  232.4
peak shear stress at 116.2 kPa  818.0  563.0  7.054  2798.0  -3.000  232.4
residual shear stress, by hand (r1)  2454.0  400.0  33.740  2571.0  -5.277  165.1
                               (r2)  4090.0  440.0  40.020  2369.0  -7.296  181.6
                               (r3)  5726.0  470.0  56.320  2193.0  -9.055  194.0
                               (r4)  7362.0  475.0  72.670  2070.0  -10.685  196.0
                               (r5)  8998.0  445.0  89.090  1892.0  -12.064  183.7
residual shear stress, (r6)  9816.0  0.0  98.160  1721.0  -13.773  0.0
machine speed at 0.5 %/hr.  9831.5  12.5  98.290  1716.0  -13.803  5.2
                               9865.0  39.7  98.771  1716.0  -13.823  16.4
                               9908.0  106.0  98.876  1708.0  -13.903  43.7
                               10307.0  571.0  102.720  1661.0  -14.373  235.7
                               10428.5  565.5  103.154  1657.0  -14.413  233.4
                               10489.5  561.0  103.773  1654.0  -14.443  231.5
                               10549.0  560.0  104.370  1651.0  -14.473  231.1
                               10607.0  557.0  104.956  1647.0  -14.513  229.9
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DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS	Proving	Consol	Normal
BOREHOLE NUMBER	95-10-2				Ring	Height	Stress
SAMPLE NUMBER	7	length,mm	59.50		A	0.308	21.32
SAMPLE DEPTH,m	5.8-6.0	width,mm	59.50	AREA,mm ²	3540.25	0.149	20.01
TEST DATE	86-04-08	height,mm,(H1)	25.20	VOLUME,cc	89.27	0.149	17.90

Time min	Square Root of Time / min	Normal Dial .002mm	Normal Displ. mm	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. mm	Normal Dial .002mm	Volume Strain %	Shear stress kPa	
0.00	0.0	3700.0	0.000	0.0	0.0	0.000	1982.0	0.000	0.0	
0.25	0.5	2250.0	-2.900	14.2	15.2	0.112	1970.0	-0.104	6.3	
0.50	0.7	1980.0	-3.440	26.5	18.5	0.228	1968.0	-0.156	7.6	
1.00	1.0	1350.0	-4.700	51.2	114.9	0.282	1968.0	-0.156	47.4	
1.50	1.2	1100.0	-5.200	61.5	155.0	0.303	1968.0	-0.156	64.3	
2.00	1.4	1000.0	-5.400	76.8	209.5	0.349	1969.0	-0.145	86.5	
3.00	1.7	900.0	-5.600	93.8	272.5	0.393	1969.0	-0.145	112.5	
5.00	2.2	530.0	-6.340	120.9	354.5	0.500	1961.0	-0.235	146.3	
75.00	8.7	2060	-7.172	143.5	421.5	0.592	1955.0	-0.302	174.3	
202.00	14.2	2045.0	-7.202	165.4	484.5	0.685	1948.0	-0.300	200.0	
324.00	18.0	2032.0	-7.228	183.5	528.5	0.778	1938.0	-0.492	218.1	
4191.00	64.7	2030.0	-7.232	200.0	567.8	0.864	1929.0	-0.592	234.2	
stopped overnight at 1.116 mm				216.0	601.5	0.957	1921.0	-0.682	248.2	
restarted at 1.226 mm				244.0	661.0	1.118	1909.0	-0.816	272.8	
				244.8	611.0	1.226	1889.0	-1.009	252.2	
				249.0	624.0	1.242	1882.0	-1.117	257.5	
				285.0	641.2	1.578	1882.0	-1.117	264.8	
				313.5	684.5	1.766	1873.0	-1.218	282.5	
				349.5	731.0	2.033	1859.0	-1.374	301.7	
				390.0	760.0	2.340	1842.0	-1.564	321.9	
				430.0	821.5	2.657	1824.0	-1.765	339.0	
				445.5	839.0	2.777	1818.0	-1.832	346.3	
				486.0	873.9	3.112	1806.0	-1.966	360.7	
stopped overnight at 3.27 mm				505.0	990.0	3.270	1798.0	-2.056	367.3	
restarted at 3.369 mm				505.2	841.5	3.369	1789.0	-2.156	347.3	
				529.0	907.2	3.476	1782.0	-2.235	374.4	
				556.5	930.0	3.705	1775.0	-2.313	383.8	
				590.4	943.2	4.018	1767.0	-2.402	399.3	
				623.1	961.8	4.307	1757.0	-2.514	396.9	
peak shear stress at 397.4 kPa				653.0	963.0	4.604	1750.0	-2.592	397.4	
				694.9	961.4	5.026	1740.0	-2.704	396.8	
end of peak run				728.5	955.0	5.375	1726.0	-2.744	394.1	
residual shear stress, by hand (r1)				2186.0	729.0	20.402	1538.0	-4.961	320.9	
				(r2)	3644.0	719.0	35.002	1394.0	-6.570	296.7
				(r3)	5102.0	718.0	49.584	1284	-7.799	296.3
				(r4)	6560.0	725.0	64.150	1176.0	-9.006	299.2
				(r5)	8010.0	719.0	78.742	1064.0	-10.257	296.7
residual shear stress,				(r6)	8747.0	0.2	87.470	971.0	-11.296	0.0
machine speed at 0.5 %/hr.				8764.0	10.0	87.604	962.0	-11.397	7.4	
				8784.0	36.4	87.767	961.0	-11.406	15.0	
				9270.5	971.0	90.763	934.0	-11.709	400.7	
				9335.0	957.5	91.435	935.0	-11.698	395.2	
				9408.0	934.0	92.212	932.0	-11.732	395.5	

CYCLE C

86-25-89

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER	85-10-2					Ring	Height	Stress
SAMPLE NUMBER	7	length,mm	59.50	A		0.308	21.32	299.6
SAMPLE DEPTH,m	5.8-6.0	width,mm	59.50	AREA,mm^2	7540.25	B	0.149	20.01
TEST DATE	86-04-08	height,mm,(H1)	25.20	VOLUME,cc	89.27	C	0.149	17.90
								999.5

Time	Square	Normal	Normal	Horiz	P.Ring	Horiz.	Normal	Volume	Shear
min	Root of	Dial	Displ.	Dial	Dial	Displ.	Dial	Strain	stress
	Time	.002mm	mm	.01mm	.002mm	mm	.002mm	%	kPa
/ min									
				9436.5	923.0	92.519	931.0	-11.743	380.9
				9514.0	911.0	93.318	929.0	-11.765	376.0
				9542.0	904.0	93.612	927.0	-11.788	373.1

CYCLE A

86-25-29

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER	85-10-2					Ring	Height	Stress
SAMPLE NUMBER	20	length,mm	59.50		A	0.308	22.78	198.7
SAMPLE DEPTH,mm	20.6-20.8	width,mm	59.50	AREA,mm ²	3542.25 B	0.328	22.82	400.3
TEST DATE	86-04-15	height,mm, (H1)	25.20	VOLUME,cc	89.27 C	0.311	21.15	649.9

Time (min)	Square Root of Time (min)	Normal Dial .002mm	Normal Displ. (mm)	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. (mm)	Normal Dial .002mm	Volume Strain (%)	Shear stress (kPa)
0.00	0.0	1000.0	0	0.0	0.0	0.000	2100.0	0.000	0.0
0.50	0.7	1130.0	-1.340	2.0	2.9	0.014	2100.0	0.000	2.5
1.00	1.0	840.0	-1.920	16.0	25.0	0.118	2080.0	-0.149	21.7
1.50	1.2	765.0	-2.070	26.0	36.0	0.188	2070.0	-0.237	30.7
2.00	1.4	705.0	-2.190	50.0	56.0	0.306	2055.5	-0.303	40.5
3.00	1.7	660.0	-2.260	73.5	72.0	0.591	2046.0	-0.474	61.4
4.00	2.0	643.0	-2.314	121.5	90.5	1.034	2021.0	-0.694	77.2
5.00	2.2	638.0	-2.324	140.0	95.4	1.217	2012.0	-0.773	81.4
9.00	3.0	621.0	-2.358	167.0	102.0	1.466	2000.0	-0.862	87.0
105.00	10.3	598.0	-2.404	188.0	106.9	1.666	1995.0	-0.915	91.2
110.00	11.4	594.0	-2.412	215.0	112.0	1.929	1987.0	-0.992	95.5
1084.00	32.9	583.0	-2.434	234.0	114.9	2.110	1981.0	-1.045	98.0
				403.0	129.0	3.772	1939.0	-1.414	110.1
peak shear stress at 112.9 kPa				696.5	131.5	6.702	1887.0	-1.870	112.2
				709.0	132.1	6.826	1887.0	-1.870	112.7
end of peak run				739.0	132.3	7.125	1865.0	-1.876	112.9
residual shear stress, by hand (r1)				2217.0	37.0	21.996	1636.0	-4.056	74.2
			(r2)	2695.0	60.0	26.790	1482.0	-5.426	68.2
			(r3)	5173.0	81.0	51.568	1357.0	-6.522	69.1
			(r4)	6651.0	88.0	66.304	1250.0	-7.463	75.1
			(r5)	8129.0	92.0	81.106	1172.0	-8.147	78.5
residual shear stress, (r6)				8860.0	0.0	88.680	1100.0	-8.709	0.0
machine speed at 0.5 %/hr.				8870.0	3.0	88.694	1096.0	-8.815	2.6
				8916.0	5.0	89.150	1091.0	-8.859	4.3
				9356.0	137.5	93.285	1002.0	-9.640	117.3
				9387.0	139.0	93.592	1002.0	-9.640	118.5
				9421.0	139.0	93.932	1006.0	-9.605	118.6
				9446.0	140.0	94.180	1006.0	-9.605	119.4
				9475.0	140.4	94.469	1006.0	-9.605	119.8
				9510.0	140.9	94.818	1007.0	-9.596	120.2
				9544.0	141.0	95.155	1007.0	-9.596	120.2
				9582.0	141.1	95.368	1007.5	-9.592	120.4

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER	85-10-2					Ring	Height	Stress
SAMPLE NUMBER	20	length,mm	59.50		A	0.308	22.78	198.7
SAMPLE DEPTH,m	20.6-20.8	width,mm	59.50	AREA,mm ²	3540.25	B	0.308	22.02
TEST DATE	86-04-15	height,mm, (H1)	25.20	VOLUME,cc	99.27	C	0.311	21.15
								649.9

Time (min)	Square Root of Time (min)	Normal Dial .002mm	Normal Displ. (mm)	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. (mm)	Normal Dial .002mm	Volume Strain (%)	Shear stress (kPa)
0.00	0.0	2300.0	0.000	0.0	0.0	0.000	2200.0	0.000	0.0
1.00	1.0	1022.0	-2.556	3.0	6.0	0.018	2198.7	-0.012	5.1
1.50	1.2	946.0	-2.708	32.0	67.1	0.186	2179.0	-0.191	57.2
2.00	1.4	915.0	-2.770	40.0	79.0	0.242	2174.0	-0.236	67.4
2.50	1.6	880.0	-2.800	59.5	102.2	0.391	2155.0	-0.409	87.2
3.00	1.7	890.0	-2.820	69.8	113.0	0.472	2144.5	-0.504	96.4
3.50	1.9	883.0	-2.834	76.2	119.3	0.523	2139.8	-0.547	101.8
4.00	2.0	879.0	-2.842	97.5	137.0	0.701	2122.0	-0.708	116.9
7.00	2.6	866.0	-2.868	112.1	148.1	0.825	2110.0	-0.817	126.3
23.00	4.8	847.0	-2.906	134.2	163.5	1.015	2093.0	-0.972	139.5
47.00	6.9	841.0	-2.918	146.0	171.0	1.118	2085.5	-1.040	145.9
3893.00	62.4	810.0	-2.980	176.0	187.3	1.385	2066.3	-1.214	159.9
				184.7	191.6	1.464	2064.0	-1.235	163.5
				200.2	199.3	1.603	2051.6	-1.348	170.0
peak shear stress at 222.7 kPa				226.0	210.0	1.840	2039.0	-1.462	179.2
				267.0	225.5	2.219	2019.0	-1.644	192.4
				396.0	252.0	3.456	1976.0	-2.034	215.0
				692.0	261.0	6.398	1916.0	-2.579	222.7
				728.0	260.0	6.760	1913.0	-2.607	221.9
				745.0	249.9	6.950	1909.0	-2.643	213.2
end of peak run				760.0	249.0	7.102	1908.0	-2.652	212.4
residual shear stress, by hand (r1)				2280.0	175.0	22.450	1627.0	-5.204	149.3
			(r2)	3800.0	164.0	37.672	1532.0	-6.067	139.9
			(r3)	5320.0	183.0	52.834	1377.0	-7.475	156.1
			(r4)	6840.0	192.0	68.016	1268.0	-8.465	163.0
			(r5)	8360.0	210.0	83.180	1182.0	-9.246	179.2
residual shear stress,			(r6)	9120.0	0.0	91.200	1182.0	-9.246	0.0
machine speed at 0.5 %/hr.				9146.5	65.0	91.335	1182.0	-9.246	55.5
				9172.0	106.0	91.508	1170.0	-9.355	90.4
				9205.0	144.5	91.769	1151.2	-9.526	123.3
				9251.0	186.2	92.138	1136.5	-9.659	158.8
				9449.0	262	93.966	1127.0	-9.746	223.5
				9738.0	266.5	96.847	1023.0	-10.690	227.4
				9764.5	266.3	97.112	1022.0	-10.699	227.2
				9808	266	97.548	1021.0	-10.708	226.9
				9837	265	97.840	1020.7	-10.711	226.1

CYCLE C

36-05-09

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol	Normal
BOREHOLE NUMBER	85-10-2					Ring	Height	Stress
SAMPLE NUMBER	20	length,mm	59.50		A	0.308	22.78	198.7
SAMPLE DEPTH,m	20.6-20.9	width,mm	59.50	AREA,mm ²	3542.25	B	0.308	22.02
TEST DATE	86-04-15	height,mm,(H1)	25.20	VOLUME,cc	89.27	C	0.311	21.15
								649.9

Time (min)	Square Root of Time (min)	Normal Dial .002mm	Normal Displ. (mm)	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. (mm)	Normal Dial .002mm	Volume Strain (%)	Shear stress (kPa)
0.00	0.0	4645.0	0.000	0.0	0.0	0.000	2700.0	0.000	0.0
1.00	1.0	2950.0	-3.390	10.0	32.5	0.035	2697.0	-0.028	28.0
1.50	1.2	2891.0	-3.508	26.5	73.9	0.117	2688.0	-0.113	63.7
2.00	1.4	2855.0	-3.580	44.0	110.0	0.220	2674.0	-0.246	94.8
3.00	1.7	2830.0	-3.630	55.0	133.2	0.284	2667.5	-0.307	114.7
4.00	2.0	2811.0	-3.668	67.5	153.0	0.369	2654.0	-0.435	131.8
5.00	2.2	2802.0	-3.686	82.5	175.1	0.475	2640.0	-0.567	150.8
10.00	3.2	2781.0	-3.728	108.4	219.0	0.646	2620.0	-0.756	198.6
59.00	7.7	2757.0	-3.776	142.5	254.7	0.916	2596.2	-0.982	219.4
130.00	11.4	2745.5	-3.799	162.0	271.0	1.076	2586.0	-1.078	234.1
213.00	14.6	2735.2	-3.820	179.0	291.9	1.206	2577.0	-1.163	251.4
1294.00	36.0	2722.1	-3.846	211.0	315.0	1.400	2567.0	-1.296	271.3
				233.6	332.3	1.670	2552.0	-1.399	286.7
				241.5	333.5	1.748	2545.0	-1.466	287.3
				470.8	441.0	3.824	2460.0	-2.269	380.6
peak shear stress at 400.5 kPa				750.0	463.5	6.573	2404.0	-2.799	399.3
				793.0	464.7	7.001	2397.9	-2.857	400.3
end of peak run				802.0	464.9	7.090	2396.1	-2.874	400.5
residual shear stress, by hand (r1)				2406.0	378.0	23.304	2104.0	-5.636	325.6
		(r2)		4010.0	362.0	39.376	1939.0	-7.196	311.8
		(r3)		5614.0	350.0	55.440	1783.0	-8.671	301.5
		(r4)		7218.0	378.0	71.440	1655.0	-9.882	318.7
		(r5)		8822.0	400.0	87.420	1528.0	-11.003	344.6
residual shear stress,		(r6)		9624.0	0.0	96.240	1368.0	-12.596	0.0
machine speed at 0.5 %/hr.				9626.0	0.0	96.242	1363.0	-12.643	7.6
				9644.0	57.9	96.324	1357.0	-12.700	49.9
				9679.0	126.0	96.538	1347.0	-12.794	100.5
				9707.0	173.1	96.724	1340.0	-12.860	149.1
				9739.0	212.8	96.964	1334.0	-12.917	183.3
				9803.0	153.0	97.724	1322.0	-13.031	131.8
				9862.0	284.0	98.052	1304.0	-13.012	244.6
				9915.0	337.0	98.476	1278.0	-12.955	290.3
				10360.0	391.1	102.818	1336.0	-12.598	336.9
				10404.0	391.1	103.258	1335.0	-12.928	336.9
				10418.0	391.0	103.398	1335	-12.908	336.8

CYCLE A

96-05-89

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol.	Normal
BOREHOLE NUMBER	85-10-2					Ring	Height	Stress
SAMPLE NUMBER	28	length,mm	59.50		A	0.043	21.50	302.0
SAMPLE DEPTH,m	29.7-29.9	width,mm	59.50	AREA,mm2	3540.25	B	0.308	20.43
TEST DATE	86-04-09	height,mm	25.20	VOLUME,cc	89.27	C	0.149	16.02

Time min	Square Root of Time / min	Normal Dial .002mm	Normal Displ. mm	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. mm	Normal Dial .002mm	Volume Strain %	Shear stress kPa
0.00	0.0	5700.0	0	0.0	0.0	0.000	3819.0	0.000	0.0
0.50	0.7	4300.0	-2.800	14.0	25.5	0.089	3795.0	-0.223	3.0
1.00	1.0	4220.0	-2.960	20.2	25.9	0.230	3780.0	-0.208%	3.1
2.00	1.4	4153.0	-3.094	37.0	39.0	0.292	3707.4	-0.294%	4.6
2.50	1.6	4134.0	-3.132	50.0	120.5	0.339	3704.1	-0.325%	14.3
3.00	1.7	4120.0	-3.160	90.0	136.0	0.628	3779.0	-0.372%	16.2
4.00	2.0	4092.0	-3.216	132.6	260.0	0.806	3764.0	-0.512%	31.0
14.00	3.7	3946.0	-3.500	152.5	322.6	0.800	3759.0	-0.559%	38.4
32.00	5.7	3893.0	-3.614	186.0	411.0	1.038	3753.0	-0.614%	49.0
102.00	10.1	3864.0	-3.672	210.0	459.9	1.100	3744.9	-0.609%	54.0
353.00	18.8	3856.0	-3.680	232.0	482.0	1.356	3726.0	-0.865%	57.4
1329.00	36.5	3850.0	-3.700	252.0	515.0	1.490	3718.0	-0.940%	61.3
				439.0	767.0	2.856	3643.0	-1.637%	91.3
peak shear stress at 96.7 kPa				747.0	812.2	5.846	3550.0	-2.428%	96.7
				750.0	794.0	5.992	3555.0	-2.456%	94.6
end of peak run				794.0	700.0	6.540	3550.0	-2.502%	93.4
residual shear stress, by hand (r1)				2302.0	271.0	23.278	3387.0	-4.019%	32.3
			(r2)	3970.0	710.0	30.200	3318.0	-4.660%	84.6
			(r3)	5550.0	682.0	54.216	3260.0	-5.126%	81.2
			(r4)	7146.0	645.0	70.170	3236.0	-5.423%	76.8
			(r5)	8734.0	630.0	86.080	3211.0	-5.656%	75.0
residual shear stress,			(r6)	9528.0	0.0	95.200	3071.0	-6.958%	0.0
machine speed at 0.5 %/hr.				9555.0	13.0	95.524	3049.0	-7.163%	1.5
				9603.0	226.0	95.578	3041.0	-7.237%	26.9
				10003.0	670.0	99.490	2979.0	-7.814%	79.8
				10110.0	772.0	99.556	2976.0	-7.842%	91.9
				10134.0	821.0	99.698	2970.0	-7.890%	97.8
				10169.0	825.0	100.040	2966.0	-7.935%	98.3
				10213.0	827.0	100.476	2963.0	-7.963%	98.5
				10232.0	825.0	100.670	2961.0	-7.981%	98.3

DIRECT SHEAR TESTS

PROJECT NUMBER	851-1298	BOX DIMENSIONS	SAMPLE DIMENSIONS		Proving	Consol.	Normal
BOREHOLE NUMBER	85-10-2				Ring	Height	Stress
SAMPLE NUMBER	28	length,mm	59.50		A	0.043	302.8
SAMPLE DEPTH,m	29.7-29.8	width,mm	59.50	AREA,mm ²	3540.25	0.308	500.0
TEST DATE	86-04-09	height,mm	25.20	VOLUME,cc	89.27	0.149	699.7

Time min	Square Root of Time / min	Normal Dial .002mm	Normal Displ. mm	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. mm	Normal Dial .002mm	Volume Strain %	Shear stress kPa	
0.00	0.0	2140.0	0.000	0.0	0.0	0.000	1425.0	0.000	0.0	
0.50	0.7	1150.0	-1.980	10.1	29.5	0.042	1374.0	-0.499	25.2	
1.00	1.0	980.0	-2.320	33.1	71.0	0.109	1350.0	-0.734	60.6	
1.50	1.2	855.0	-2.570	48.0	90.0	0.300	1338.0	-0.852	76.8	
2.00	1.4	820.0	-2.640	58.1	101.5	0.378	1330.0	-0.930	86.6	
2.50	1.6	620.0	-3.040	73.0	114.5	0.501	1319.0	-1.038	97.7	
3.00	1.7	550.0	-3.180	94.5	130.0	0.605	1302.0	-1.204	110.9	
4.00	2.0	435.0	-3.410	119.2	144.0	0.904	1286.0	-1.361	122.8	
5.00	2.2	357.0	-3.566	142.5	154.2	1.117	1272.0	-1.498	131.6	
6.00	2.4	290.0	-3.700	171.2	165.0	1.382	1252.0	-1.694	140.6	
7.00	2.6	2059.0	-3.774	190.0	171.0	1.558	1242.0	-1.791	145.9	
11.00	3.3	1920.0	-4.050	225.5	181.0	1.893	1223.0	-1.977	154.4	
13.00	3.6	1810.0	-4.270	243.0	184.9	2.060	1214.0	-2.066	157.7	
970.00	31.1	1560.0	-4.770	402.5	205.5	3.614	1145.0	-2.741	175.3	
peak shear stress at 176.5 kPa				702.5	206.9	6.611	1086.0	-3.319	176.5	
				730.0	203.0	6.894	1002.0	-3.350	173.2	
				751.5	202.2	7.111	1000.0	-3.377	172.5	
end of peak run				780.0	201.5	7.397	1075.0	-3.426	171.9	
residual shear stress, by hand (r1)				2340.0	130.0	23.140	990.0	-4.258	110.9	
				(r2)	3900.0	90.0	38.004	940.0	-4.740	95.6
				(r3)	5460.0	85.0	54.430	895.0	-5.190	72.5
				(r4)	7020.0	79.0	70.042	857.0	-5.560	67.4
				(r5)	8580.0	79.0	85.642	820.0	-5.044	67.4
residual shear stress,				(r6)	9360.0	0.0	93.600	607.0	-8.000	0.0
machine speed at 0.5 %/hr.				9379.0	60.6	93.669	607.0	-8.000	51.7	
				9418.0	122.0	93.936	593.0	-8.145	104.1	
				9476.0	166.0	94.426	581.0	-8.262	142.0	
				9641.7	185.0	96.047	563.0	-8.439	157.8	
				9682.0	180.2	96.444	559.0	-8.478	160.6	
				10062.0	180.5	100.243	550.0	-8.566	160.8	
				10114.0	180.3	100.763	547.0	-8.587	160.6	
				10138.0	180.3	101.000	547.0	-8.587	160.6	
				10151.0	180.3	101.133	547.0	-8.587	160.6	

CYCLE C

86-05-09

DIRECT SHEAR TESTS

PROJECT NUMBER 851-1298		BOX DIMENSIONS		SAMPLE DIMENSIONS		Proving	Consol.	Normal
BOREHOLE NUMBER 85-10-2						Ring	Height	Stress
SAMPLE NUMBER	28	length,mm	59.50	A	0.043	21.50	302.0	
SAMPLE DEPTH,m	29.7-29.8	width,mm	59.50	AREA,mm2	3540.25	B	0.308	502.0
TEST DATE	86-04-09	height,mm	25.20	VOLUME,cc	89.27	C	0.149	699.7

Time min	Square Root of Time / min	Normal Dial .002mm	Normal Displ. mm	Horiz Dial .01mm	P.Ring Dial .002mm	Horiz. Displ. mm	Normal Dial .002mm	Volume Strain %	Shear stress kPa
0.00	0.0	2700.0	0.000	0.0	0.0	0.000	1838.0	0.000	0.0
0.50	0.7	1350.0	-2.700	5.1	17.0	0.017	1689.0	-1.860	7.0
1.00	1.0	1064.0	-3.272	30.0	27.0	0.246	1679.0	-1.985	11.1
1.50	1.2	850.0	-3.700	45.5	50.5	0.338	1675.0	-2.035	24.1
2.00	1.4	580.0	-4.240	61.5	114.5	0.386	1671.0	-2.085	47.3
2.50	1.6	280.0	-4.840	75.0	157.0	0.436	1667.0	-2.135	64.8
3.00	1.7	45.0	-5.310	98.0	214.2	0.552	1657.0	-2.260	88.4
3.50	1.9	3705.0	-5.760	121.0	259.5	0.691	1646.0	-2.397	107.1
4.00	2.0	3534.0	-6.102	143.0	296.2	0.838	1637.0	-2.509	122.2
5.00	2.2	3230.0	-6.710	178.5	349.5	1.086	1622.0	-2.697	144.2
10.00	3.2	2570.0	-8.014	197.5	371.5	1.232	1613.0	-2.809	153.3
15.00	3.9	2441.0	-8.288	232.0	391.8	1.536	1597.0	-3.009	161.7
24.00	4.9	2273.0	-8.715	251.0	427.5	1.655	1586.0	-3.146	176.4
977.00	31.3	1994.0	-9.182	416.0	518.5	3.123	1513.0	-4.057	214.0
				742.0	471.5	6.477	1452.0	-4.819	194.6
peak shear stress at 214.2 kPa				768.0	457.5	6.765	1447.0	-4.881	188.8
				790.0	448.0	7.004	1444.0	-4.919	184.9
end of peak run				809.0	448.0	7.194	1442.0	-4.944	184.9
residual shear stress, by hand (r1)				2427.0	285.0	23.700	1327.0	-6.379	117.6
			(r2)	4045.0	250.0	39.950	1245.0	-7.403	103.2
			(r3)	5663.0	245.0	56.140	1198.0	-7.990	101.1
			(r4)	7281.0	260.0	72.290	1138.0	-8.739	107.3
			(r5)	8699.0	260.0	88.470	1102.0	-9.188	107.3
residual shear stress,			(r6)	9708.0	0.0	97.000	980.0	-10.712	0.0
machine speed at 0.5 %/hr.				9731.0	9.2	97.292	976.0	-10.762	3.8
				9772.0	34.8	97.650	979.0	-10.724	14.4
				9831.0	91.0	98.128	927.0	-11.373	37.6
				9894.5	396.0	98.153	965.0	-10.899	163.4
				9937.0	434.0	98.502	960.0	-10.961	179.1
				10455.0	376.0	103.798	954.0	-11.036	155.2
				10465.0	376.0	103.898	950.0	-11.086	155.2

APPENDIX 3

SUMMARY OF WATER CONTENT DETERMINATIONS

Samples Received June 20, 1986

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SUMMARY OF WATER CONTENT DETERMINATIONS

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PROJECT NUMBER 851-1298

PROJECT NAME Gartner Lee/OWMC 4B/85-GT-4

DATE TESTED June 20, 1986

=====

GLA Tare No.	Water Content %
X948	19.1
X943	22.0
X979	25.5
X143	24.6
X245	20.8
X901	30.2
4	28.4
281	22.1
873	21.6
822	23.6
881	20.5
GM63	32.1
S16	18.7
S52	19.7
A56	24.3
N160	20.7
N172	24.7
P34	34.2

E2 GRAIN SIZE DISTRIBUTION CURVES

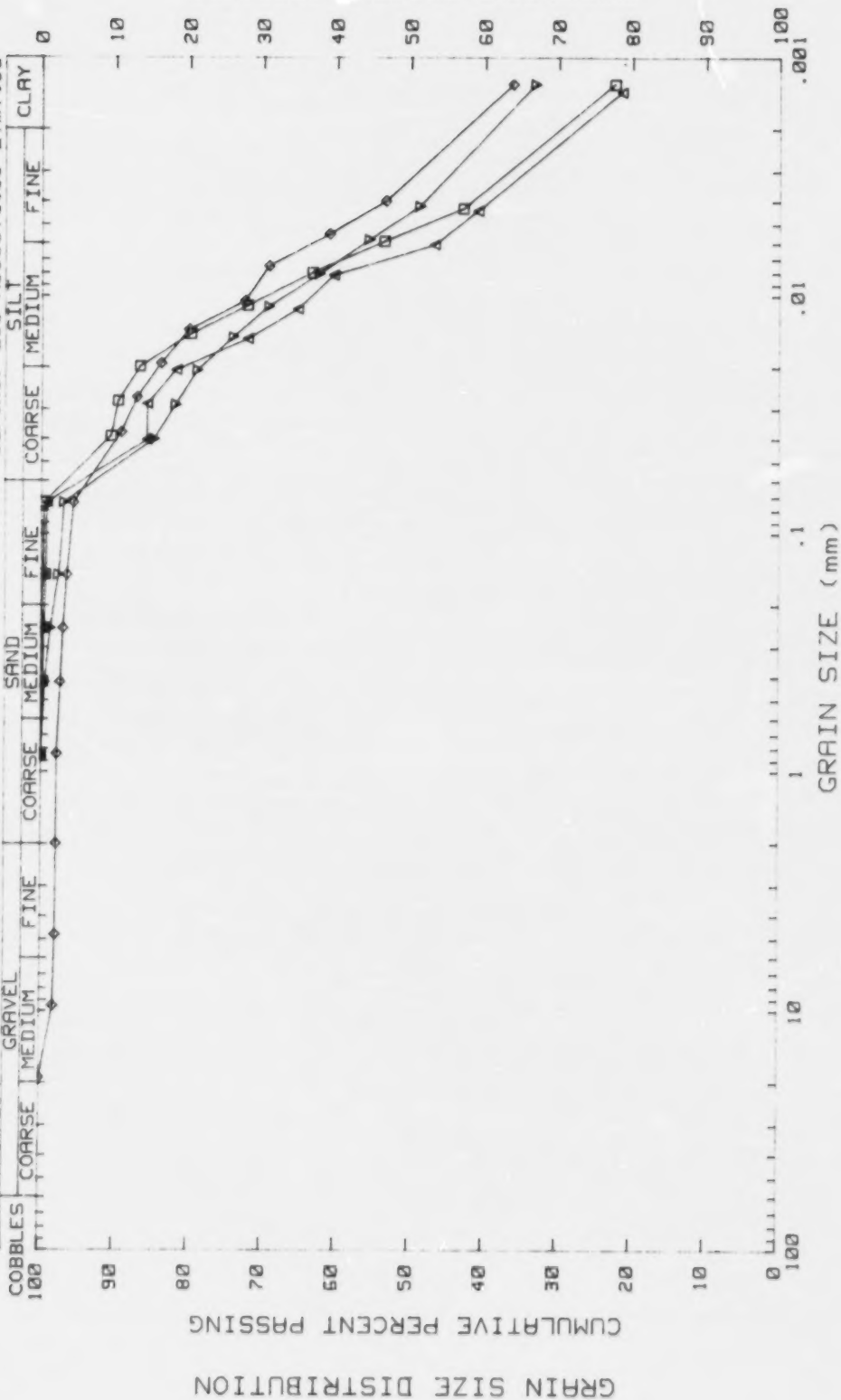
Appendix E2 presents a summary of the grain size analyses data presented in the Golder Associates (Eastern Canada) Ltd. report. For convenience the data have been plotted separately by geologic unit.

OWMC, PHASE 4B GEOSCIENCE PROGRAM

85-GT-6

Modified M.I.T. Grain Size Scale

Gartner Lee Associates Limited



- △ Borehole 8-2, Sample 4, Depth 2.74-3.35 m, Gravel 0%, Sand 5.5%, Silt 67%, Clay 27.5%
- Borehole 12-2, Sample 4, Depth 2.7-3.4 m, Gravel 0%, Sand 3.4%, Silt 66.8%, Clay 29.8%
- ▽ Borehole 8-2, Sample 7, Depth 5.5-6.11 m, Gravel 0%, Sand 7.3%, Silt 53.9%, Clay 38.8%
- ◇ Borehole 10-2, Sample 7, Depth 5.5-6.1 m, Gravel 2.2%, Sand 4.2%, Silt 50.8%, Clay 42.8%

FIGURE E2-1: GRAIN SIZE DISTRIBUTION, UPPER GLACIOLACUSTRINE SUBUNITS 1A AND 1C

OWMC, PHASE 4B GEOSCIENCE PROGRAM

Modified M.I.T. Grain Size Scale

85-GT-6

Gartner Lee Associates Limited

COBBLES
100
90
80
70
60
50
40
30
20
10
0

GRAVEL
COARSE
MEDIUM
FINE

SAND
COARSE
MEDIUM
FINE

SILT
COARSE
MEDIUM
FINE

CLAY

GRAIN SIZE DISTRIBUTION

CUMULATIVE PERCENT PASSING

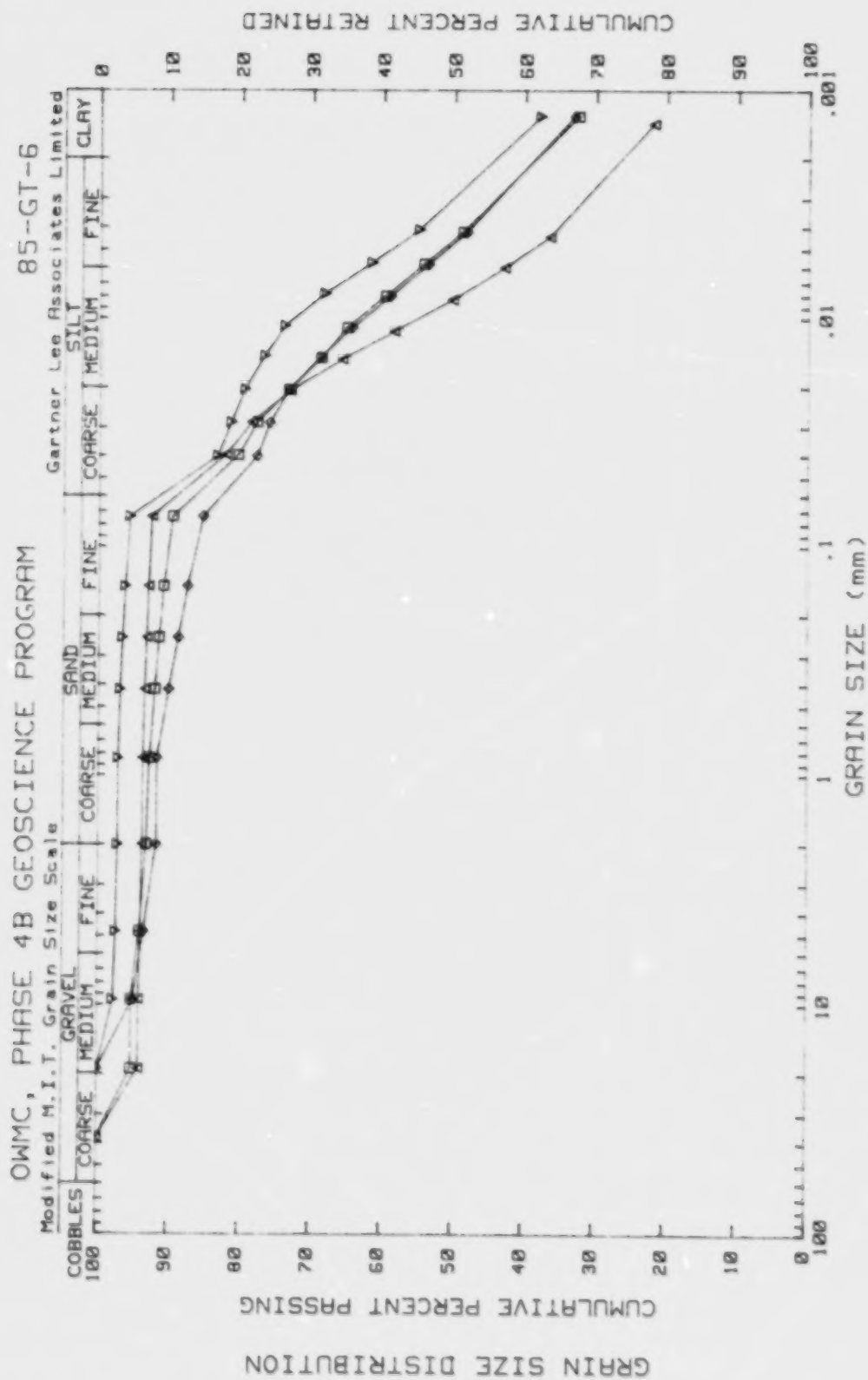
CUMULATIVE PERCENT RETAINED

GRAIN SIZE (mm)

100
10
1
.1
.01
.001

- △ Borehole 3-2, Sample 6, Depth 4.6-5.2 m, Gravel 0%, Sand 2%, Silt 31.4%, Clay 66.6%
- Borehole 1-2, Sample 7, Depth 5.03-5.64 m, Gravel .4%, Sand 3.3%, Silt 39.9%, Clay 56.4%

FIGURE E2-2: GRAIN SIZE DISTRIBUTION, UPPER GLACIOLACUSTRINE SUBUNIT 1B

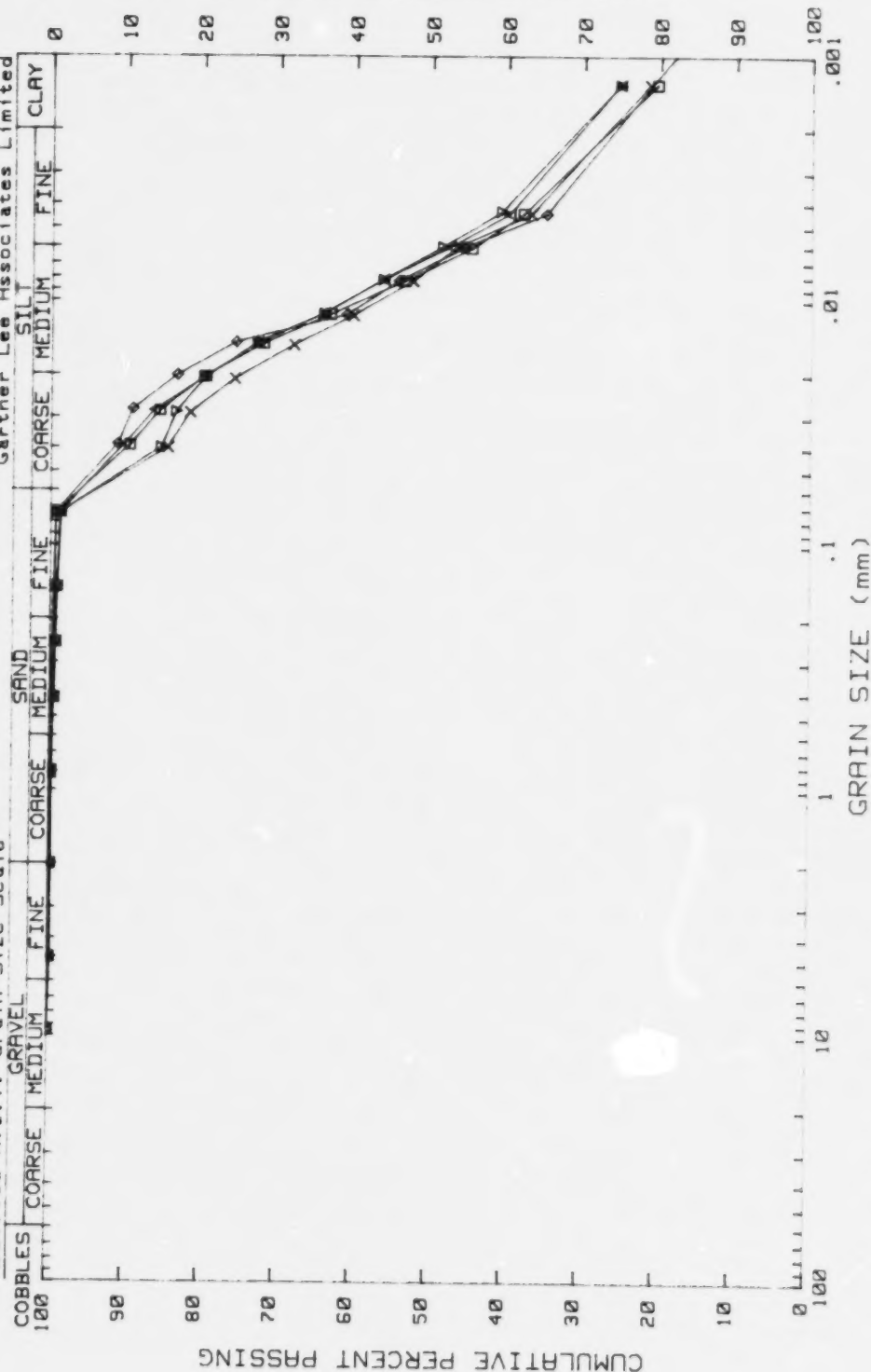


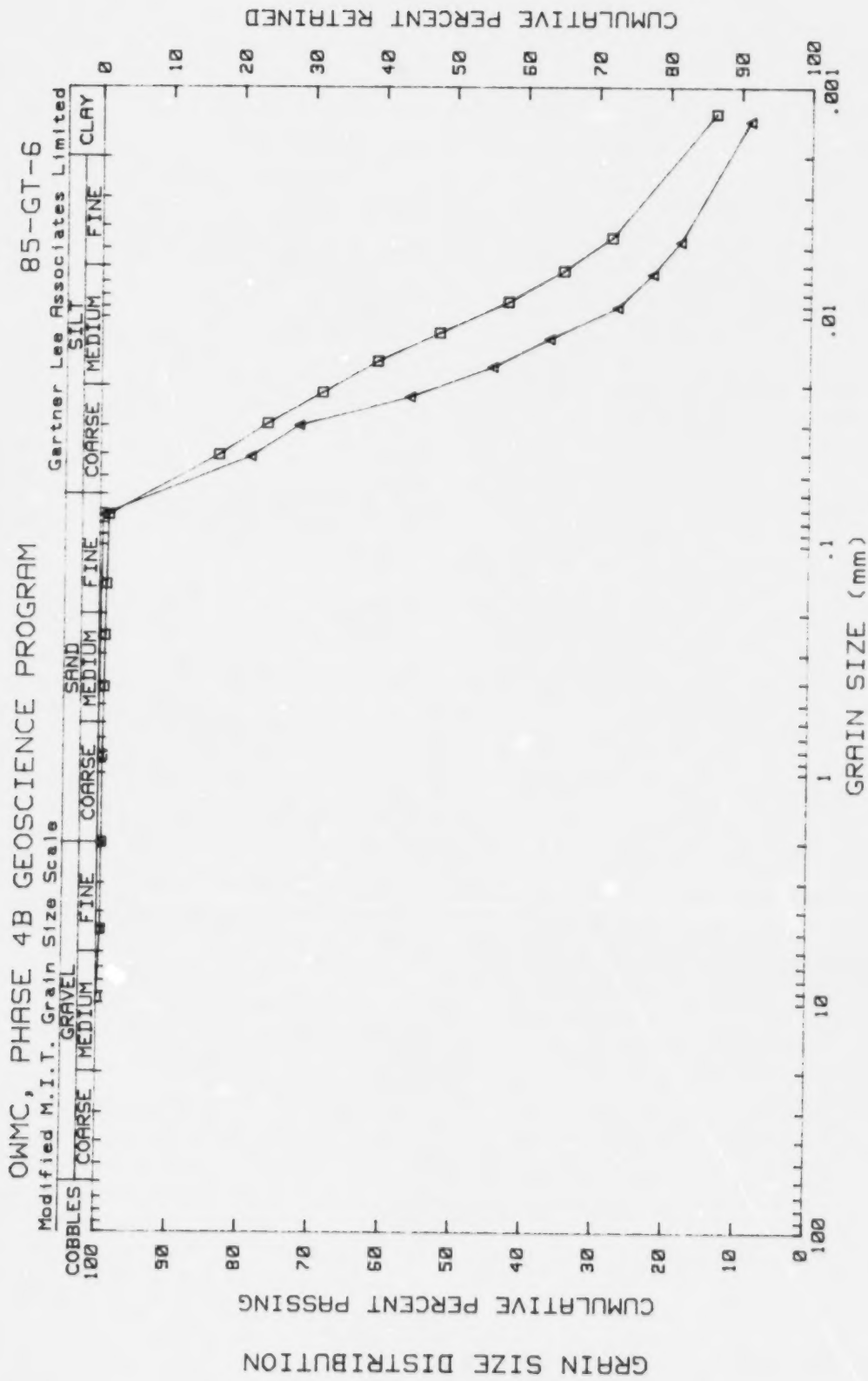
OWMC, PHASE 4B GEOSCIENCE PROGRAM

85-GT-6

Gartner Lee Associates Limited

Modified M.I.T. Grain Size Scale





△ Borehole 10-2, Sample 16, Depth 15.7-16.3 m, Gravel 0%, Sand 7.8%, Silt 80.6%, Clay 11.6%
 □ Borehole 12-2, Sample 15, Depth 15.7-16.3 m, Gravel .5%, Sand 6.1%, Silt 74.8%, Clay 18.6%

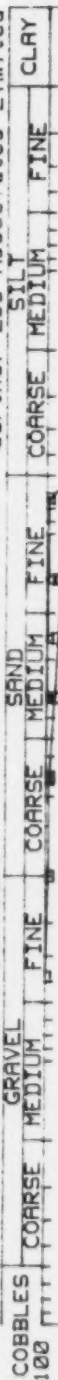
FIGURE E2-5: GRAIN SIZE DISTRIBUTION, HALTON SUBUNIT 2B

OWMC, PHASE 4B GEOSCIENCE PROGRAM

85-GT-6

Modified M.I.T. Grain Size Scale

Gartner Lee Associates Limited

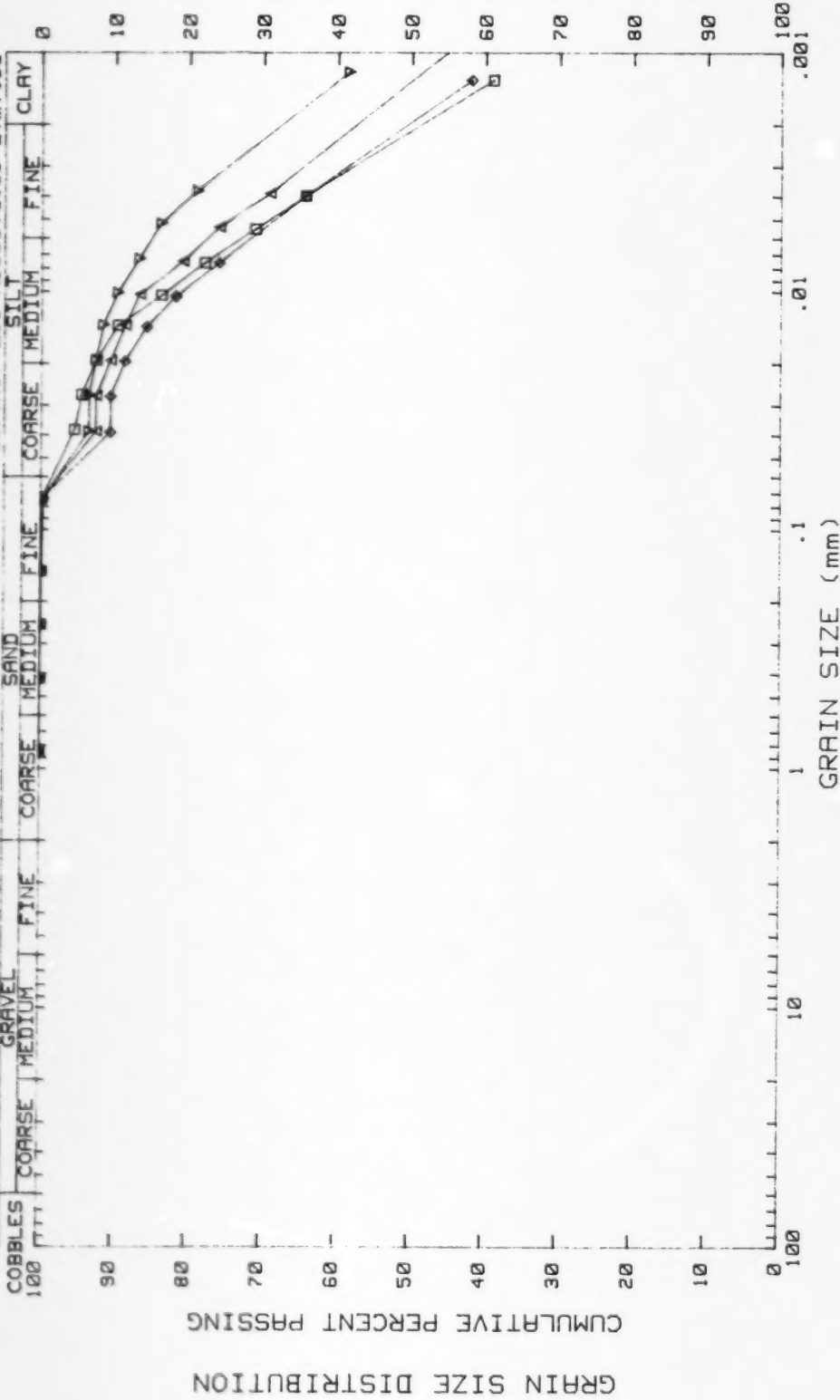


OWMC, PHASE 4B GEOSCIENCE PROGRAM

85-GT-6

Modified M.I.T. Grain Size Scale

Gartner Lee Associates Limited



OWMC, PHASE 4B GEOSCIENCE PROGRAM

85-GT-6

Gartner Lee Associates Limited

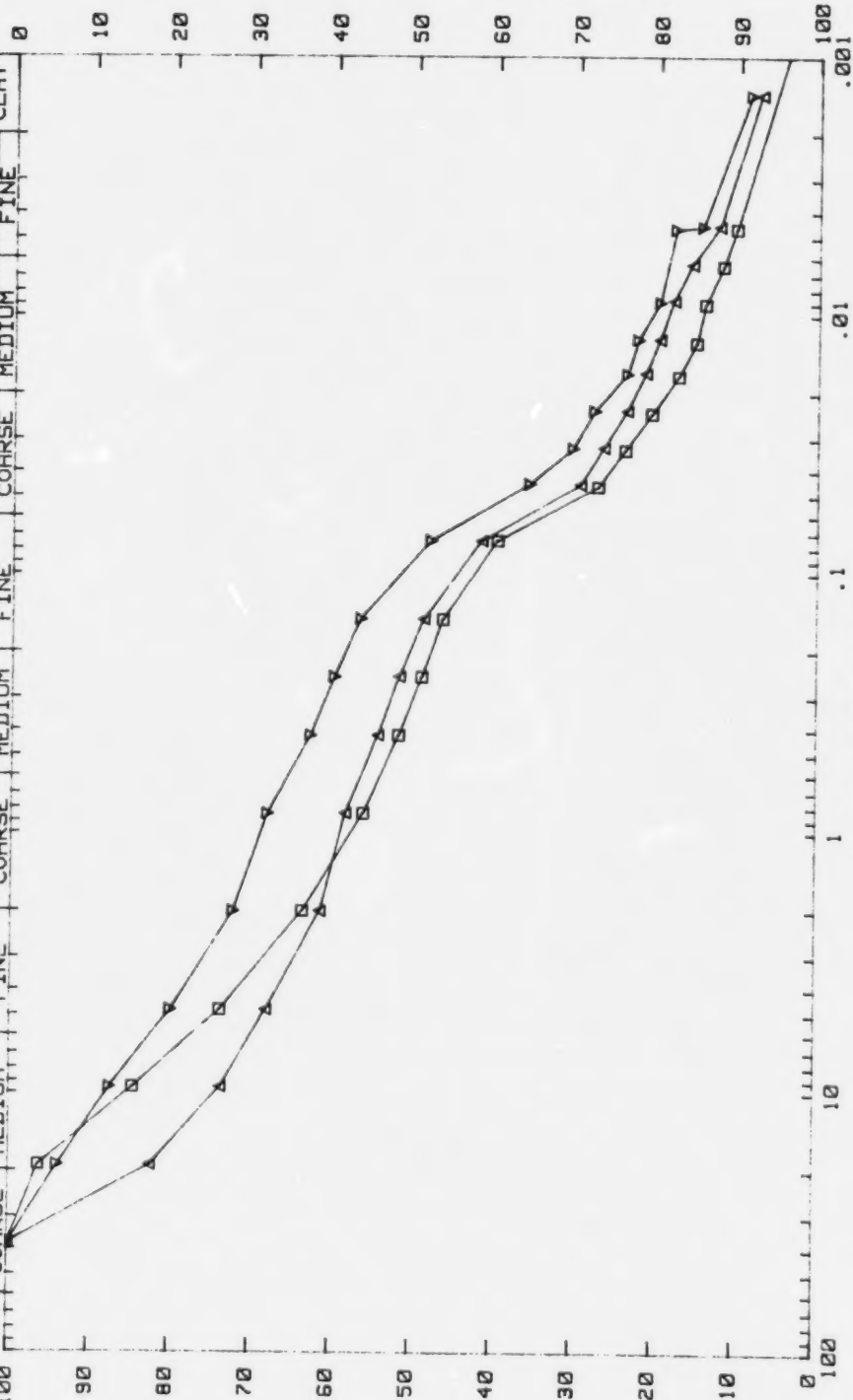
Modified M.I.T. Grain Size Scale

COBBLES COARSE GRAVEL MEDIUM FINE SAND COARSE MEDIUM FINE SILT CLAY

GRAIN SIZE DISTRIBUTION

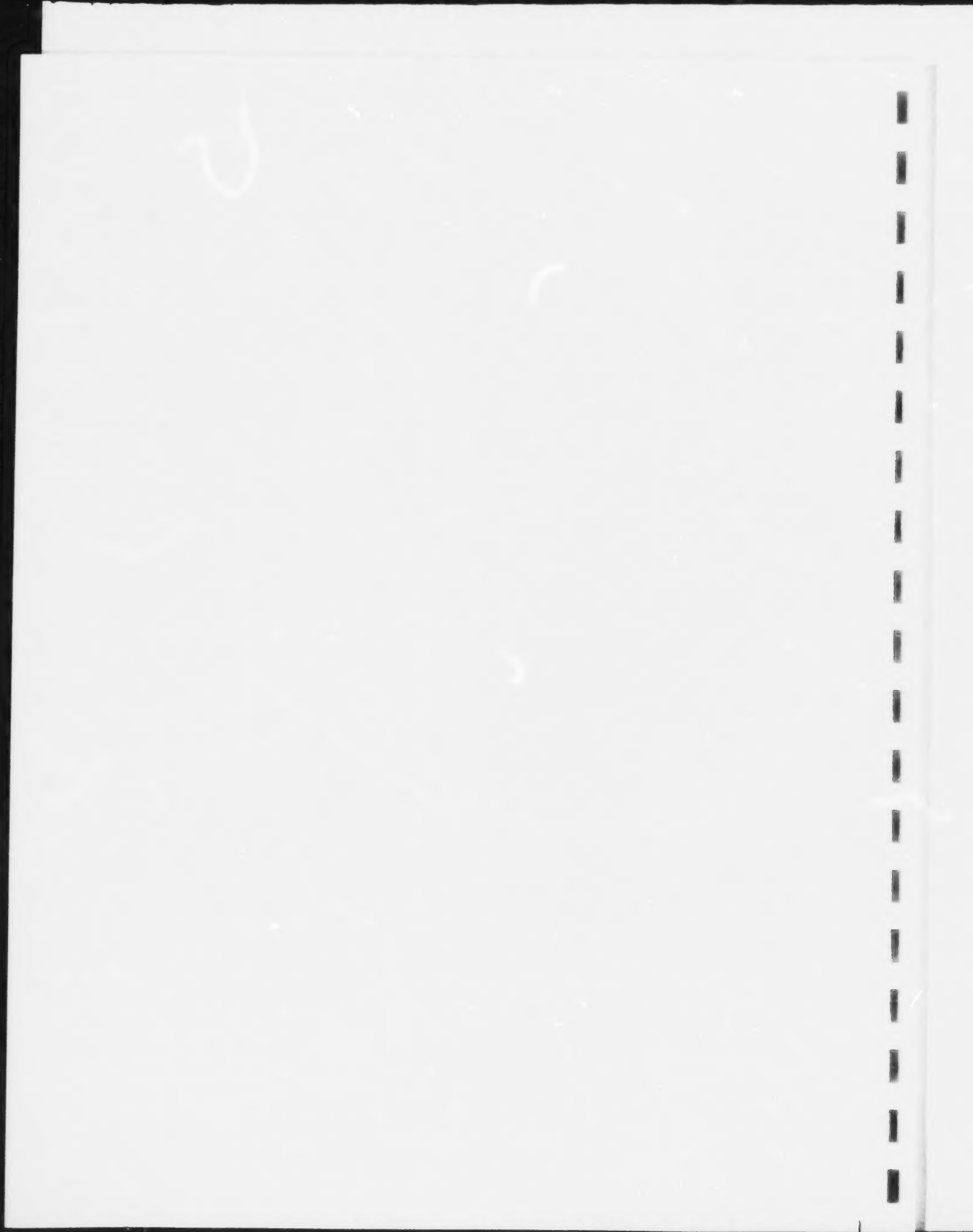
CUMULATIVE PERCENT PASSING

GRAIN SIZE (mm)



- △ Borehole 10-2, Sample 30, Depth 32.0-32.5 m, Gravel 38.6%, Sand 24.8%, Silt 27.6%, Clay 9%
- Borehole 2-2, Sample 27, Depth 32.5-33.0 m, Gravel 36.4%, Sand 29.2%, Silt 27.5%, Clay 6.9%
- ▽ Borehole 8-2, Sample 30, Depth 32.91-33.50 m, Gravel 27.9%, Sand 29.2%, Silt 32.5%, Clay 10.4%

FIGURE E2-8: GRAIN SIZE DISTRIBUTION, LOWER TILL UNIT 4



F-1

APPENDIX F

INSTRUMENTATION AND WATER LEVEL DATA

APPENDIX F

INSTRUMENTATION AND WATER LEVEL DATA

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F2-1 WATER LEVEL DATA	F-12

F1 MONITOR DETAILS

This appendix provides construction details for each of the ground water monitors installed during the 1985 Phase 4B geoscience program. Monitors are identified by year, location number and monitor number. The protocols for monitor installation were presented in Appendix A2. Appendix A2 also introduces the monitor construction terminology used here.

Table F1-1 summarizes the major construction details of the monitors, including monitor inside diameter, ground elevation, stick up (length of monitor pipe above grade), top of monitor elevation, monitor type, and the location of the screen, sand pack and seal. All measurements were taken during the installation of each monitor.

Table FI-1

F-4

Ground Water Monitor Details

MONITOR NO	MONITOR INSIDE DIAMETER	BOREHOLE DIAMETER	GROUND ELEVATION	STICK UP	TOP OF MONITOR	MONITOR TYPE	SCREENED INTERVAL		SAND PACK		SEAL	
							DEPTH FROM GRADE	ELEVATION	DEPTH FROM GRADE	ELEVATION	DEPTH FROM GRADE	ELEVATION
85-	feet	feet	feet & S.L.	feet	feet & S.L.		feet	feet & S.L.	feet	feet & S.L.	feet	feet & S.L.
1-1	52	96	185.58	0.30	185.88	P	34.40 to 37.50	151.18 to 148.88	34.30 to 37.50	151.20 to 148.88	29.70 to 34.59	155.88 to 151.29
1-2	19	51	185.57	0.52	186.09	P	32.29 to 33.23	153.34 to 152.34	32.88 to 33.23	153.57 to 152.34	28.89 to 30.59	163.57 to 153.57
1-3	19	51	185.32	0.55	185.87	P	29.91 to 26.91	159.41 to 158.41	29.58 to 27.13	159.82 to 158.19	21.88 to 23.59	164.58 to 159.88
1-4	19	51	185.28	0.55	185.83	P	15.24 to 16.24	178.84 to 169.84	15.88 to 16.46	178.28 to 168.82	11.88 to 13.88	174.28 to 170.28
1-5	19	51	185.89	0.49	185.69	S	1.18 to 5.18	183.91 to 179.91	0.91 to 5.48	184.18 to 179.61	0.58 to 8.91	184.58 to 184.18
1-6		182	185.36	0.51	185.87	W	27.13	158.29	26.48 to 27.13	158.96 to 158.73	22.88 to 26.48	162.38 to 158.96
1-7		182	185.58	0.52	185.82	W	16.46	168.84	15.58 to 16.46	169.88 to 168.84	11.88 to 15.58	178.58 to 169.88
1-8	52	182	185.19	0.67	185.86	P	24.48 to 25.88	168.79 to 168.19	none-filler cloth around screen	none-filler cloth around screen	19.58 to 24.58	165.49 to 168.81
1-9	52	182	185.28	0.65	185.93	P	15.24 to 15.84	178.84 to 169.44	none-filler cloth around screen	none-filler cloth around screen	11.88 to 15.24	174.28 to 178.84
1-10	52	283	185.24	0.48	185.94	S	2.33 to 5.33	188.98 to 179.93	2.38 to 5.33	188.96 to 179.93	1.18 to 2.38	184.18 to 182.96
1-11	19	51	185.36	0.67	186.03	P	8.88 to 9.84	176.56 to 175.52	8.58 to 18.14	176.86 to 175.27	3.25 to 8.58	180.11 to 176.86
1-12a		89	185.53	0.86	186.39	W	61.58	124.83	61.12 to 61.68	124.48 to 123.93	47.88 to 61.17	138.58 to 124.48
1-12b		89	185.53	0.86	186.39	W	47.88	138.53	46.58 to 47.88	139.83 to 138.53	37.88 to 46.58	148.53 to 139.83
1-12c	52	96	185.53	0.76	186.29	P	25.48 to 36.48	158.12 to 149.13	25.88 to 37.88	158.58 to 148.53	28.88 to 36.88	155.58 to 159.53
1-13	52	188	185.48	0.56	186.04	P	1.28 to 1.58	184.28 to 183.98	1.28 to 1.58	184.28 to 183.98	1.88 to 1.28	184.48 to 184.28
1-14	52	188	185.44	0.59	186.03	P	2.28 to 2.58	183.24 to 182.94	2.13 to 2.58	183.28 to 182.94	1.88 to 2.13	184.44 to 183.28
1-15	52	188	185.47	0.58	186.05	P	2.78 to 3.88	182.77 to 182.47	2.78 to 3.88	182.77 to 182.47	1.88 to 2.78	184.27 to 182.77
1-16	52	188	185.58	0.48	186.18	P	3.78 to 4.88	181.88 to 181.58	3.78 to 4.88	181.88 to 181.58	8.98 to 3.78	184.88 to 181.88

(P)-PIEZOMETER (S)-STANDPIPE (W)-PNEUMATIC PIEZOMETER (W)-WELL
 (R)-BOREHOLE DIAMETER OPPOSITE SCREENED INTERVAL

Note: Stickup and top-of-monitor elevation for pneumatic piezometer are relative to top of protective casing

Table F1-1 Cont.

F-5

Ground Water Monitor Details

MONITOR NO.	MONITOR INSIDE DIAMETER (in.)	BOREHOLE DIAMETER (in.)	GROUND ELEVATION (to A.S.L.)	STICK UP (ft)	TOP OF MONITOR (to A.S.L.)	MONITOR TYPE	SCREENED INTERVAL		SAND PACK		SEAL	
							DEPTH FROM GRADE (ft)	ELEVATION (to A.S.L.)	DEPTH FROM GRADE (ft)	ELEVATION (to A.S.L.)	DEPTH FROM GRADE (ft)	ELEVATION (to A.S.L.)
1-07	52	100	185.55	0.34	186.11	P	4.50 to 4.80	181.05 to 180.75	4.50 to 4.80	181.05 to 180.75	0.90 to 4.50	184.65 to 181.85
1-10	52	100	185.54	0.03	186.37	P	5.20 to 5.50	180.34 to 180.04	5.20 to 5.50	180.34 to 180.04	0.00 to 5.20	184.74 to 180.34
1-19	52	100	185.66	0.41	186.07	P	6.00 to 6.30	179.66 to 179.36	6.00 to 6.30	179.66 to 179.36	1.00 to 6.00	184.66 to 179.66
1-20	52	100	185.63	0.40	186.03	P	6.70 to 7.00	178.93 to 178.63	6.65 to 7.00	178.98 to 178.63	1.00 to 6.65	184.63 to 178.98
1-25	52	100	185.59	0.40	186.07	P	7.65 to 7.96	177.94 to 177.63	7.60 to 8.00	177.99 to 177.59	0.75 to 5.60	184.84 to 179.99
1-28	96	150	185.56	0.67	186.23	W	35.30 to 37.30	150.26 to 148.26	35.00 to 37.30	150.56 to 148.26	30.00 to 35.00	155.56 to 150.56
2-1	47	96	185.00	0.62	185.62	P	35.43 to 36.95	149.57 to 148.05	34.00 to 36.95	151.00 to 148.05	27.50 to 34.00	157.50 to 151.00
2-2	19	50	185.03	0.02	185.05	P	31.00 to 32.00	153.23 to 152.23	30.60 to 32.00	154.43 to 152.13	26.50 to 30.60	158.53 to 154.43
2-3	19	50	185.04	0.41	185.45	P	25.00 to 27.00	159.24 to 158.04	25.50 to 27.10	159.54 to 157.94	21.00 to 25.50	164.04 to 159.54
2-4	19	50	185.03	0.61	185.64	P	15.50 to 16.60	169.53 to 168.43	15.00 to 16.60	170.03 to 168.43	9.00 to 15.00	176.03 to 170.03
2-5	19	50	184.91	0.77	185.68	S	2.70 to 5.70	182.21 to 179.21	0.90 to 5.70	184.01 to 179.21	0.00 to 0.90	184.11 to 184.01
3-1	50	96	185.24	0.43	185.67	P	32.00 to 34.69	153.24 to 150.55	31.50 to 34.74	153.45 to 150.50	26.27 to 31.50	158.97 to 153.45
3-2	19	50	185.49	0.97	186.46	P	30.70 to 31.62	154.79 to 153.87	30.40 to 31.70	155.09 to 153.79	26.50 to 30.40	158.99 to 155.09
3-3	19	50	185.52	0.55	186.07	P	26.10 to 27.02	159.42 to 158.50	25.86 to 27.10	159.66 to 158.42	22.00 to 25.86	162.70 to 159.66
3-4	19	50	185.54	0.45	185.99	P	15.40 to 16.32	170.14 to 169.22	14.60 to 16.40	170.94 to 169.14	11.40 to 14.60	174.14 to 170.94
3-5	19	50	185.52	0.63	186.15	S	1.50 to 5.76	183.94 to 179.76	0.05 to 5.04	184.67 to 179.68	0.45 to 0.05	185.07 to 184.67
3-6		100	185.55	0.76	186.11	W	27.30	157.97	26.50 to 27.43	158.05 to 157.92	22.00 to 26.50	162.55 to 158.05
3-7		100	185.43	0.71	186.14	W	16.39	169.04	15.61 to 16.44	169.82 to 168.99	11.04 to 15.61	173.59 to 169.82
3-8	52	100	185.47	0.50	185.97	P	24.01 to 24.62	161.46 to 160.85	none-filter cloth are- and screws	none-filter cloth are- and screws	16.90 to 24.40	168.57 to 161.07

(P)-PIEZOMETER (S)-STANDARD (W)-PNEUMATIC PIEZOMETER (W)-WELL
 (in)-BOREHOLE DIAMETER OPPOSITE SCREENED INTERVAL

Note: Stickup and top-of-monitor elevation for pneumatic piezometer are relative to top of protective casing

Table F1-1 Cont.
Ground Water Monitor Details

MONITOR NO	MONITOR INSIDE DIAMETER (in)	BOREHOLE DIAMETER (in)	GROUND ELEVATION (to A.S.L.)	STICK UP (in)	TOP OF MONITOR (to A.S.L.)	MONITOR TYPE	SCREENED INTERVAL		SAND PACK		SEAL	
							DEPTH FROM GRADE (in)	ELEVATION (to A.S.L.)	DEPTH FROM GRADE (in)	ELEVATION (to A.S.L.)	DEPTH FROM GRADE (in)	ELEVATION (to A.S.L.)
3-9	52	102	105.43	0.00	106.23	P	15.20 to 15.00	170.23 to 169.63	none-filter cloth around screen	none-filter cloth around screen	31.00 to 15.20	174.43 to 170.23
3-10	52	76	106.41	0.49	106.99	S	2.30 to 5.30	104.11 to 101.11	2.00 to 5.30	104.41 to 101.11	1.20 to 2.00	105.21 to 104.41
3-11	19	51	105.26	0.50	105.94	P	0.53 to 9.53	176.73 to 175.73	0.40 to 9.75	176.06 to 175.51	4.00 to 0.40	100.46 to 176.06
4-1	47	96	105.43	0.54	105.99	P	37.20 to 30.10	140.23 to 147.25	35.10 to 30.20	150.33 to 147.23	31.65 to 35.10	153.70 to 150.33
4-2	19	51	105.46	0.52	105.98	P	31.99 to 32.00	152.56 to 152.66	31.10 to 32.90	154.36 to 152.54	27.00 to 31.10	157.66 to 154.36
4-3	19	51	105.38	0.56	105.94	P	25.99 to 26.00	159.40 to 150.50	25.90 to 27.10	159.40 to 150.20	22.50 to 25.90	162.00 to 159.40
4-4	19	51	105.30	0.56	105.94	P	15.20 to 16.10	170.10 to 169.20	15.00 to 16.40	170.30 to 160.90	11.00 to 15.00	173.50 to 170.30
4-5	19	51	105.32	0.60	105.92	S	1.61 to 5.50	103.71 to 179.02	0.90 to 5.00	104.42 to 179.52	0.70 to 0.90	104.42 to 104.42
5-1	47	96	105.40	0.00	106.20	P	39.40 to 40.00	146.00 to 145.00	30.00 to 40.40	147.40 to 145.00	30.70 to 30.00	154.70 to 147.40
5-2	19	51	105.44	0.75	106.19	P	34.45 to 35.45	150.99 to 149.99	30.75 to 35.75	151.69 to 149.69	30.50 to 35.75	154.94 to 151.69
5-3	19	51	105.42	0.42	106.04	P	25.02 to 26.02	159.60 to 158.60	25.60 to 26.00	159.02 to 158.59	22.00 to 25.60	163.42 to 159.02
5-4	19	51	105.42	0.41	106.03	P	16.06 to 17.06	160.56 to 167.56	16.50 to 17.06	160.92 to 167.56	13.50 to 16.50	171.92 to 160.92
5-5	19	51	105.37	0.09	106.26	S	1.49 to 5.49	103.00 to 179.00	1.00 to 5.79	104.37 to 179.50	0.75 to 1.00	104.62 to 104.37
6-1	47	96	105.46	1.02	106.48	P	37.22 to 30.74	140.24 to 146.72	36.60 to 30.74	140.06 to 146.72	29.07 to 36.60	155.59 to 140.06
6-2	19	51	105.42	0.54	105.96	P	33.50 to 34.50	151.92 to 150.92	32.50 to 34.50	152.92 to 150.92	29.50 to 32.50	155.92 to 152.92
6-3	19	51	105.30	0.71	106.09	P	26.12 to 27.12	159.26 to 150.26	25.50 to 27.12	159.00 to 150.26	22.00 to 25.50	163.30 to 159.00
6-4	19	51	105.33	0.65	105.98	P	15.24 to 16.24	170.09 to 169.09	14.74 to 16.24	170.59 to 169.09	11.60 to 14.74	173.73 to 170.59
6-5	19	51	105.24	1.03	106.27	S	0.60 to 4.07	104.64 to 100.37	0.60 to 4.07	104.64 to 100.37	0.40 to 0.60	104.94 to 104.64

(P)-PIEZOMETER (S)-STAMPIPE (M)-PNEUMATIC PIEZOMETER (W)-WELL
(B)-BOREHOLE DIAMETER OPPOSITE SCREENED INTERVAL

Note: Stickup and top-of-monitor elevation for pneumatic piezometer are relative to top of protective casing

Table F1-1 Cont.
Ground Water Monitor Details

F-7

MONITOR NO. 85+	MONITOR INSIDE DIAMETER (in)	BOREHOLE DIAMETER # (in)	GROUND ELEVATION (to A.S.L.)	STICK UP (in)	TOP OF MONITOR (to A.S.L.)	MONITOR TYPE	SCREENED INTERVAL		SAND PACK		SEAL	
							DEPTH FROM GRADE (in)	ELEVATION (to A.S.L.)	DEPTH FROM GRADE (in)	ELEVATION (to A.S.L.)	DEPTH FROM GRADE (in)	ELEVATION (to A.S.L.)
7-1	47	96	104.37	0.42	104.99	P	37.43 to 38.43	146.74 to 145.74	36.39 to 36.49	147.07 to 145.68	29.58 to 36.38	159.07 to 147.07
7-2	19	51	104.39	0.52	104.91	P	33.98 to 34.98	150.49 to 149.49	33.88 to 33.10	150.59 to 149.29	30.88 to 33.88	154.39 to 150.59
7-3	19	51	104.38	0.48	104.86	P	25.99 to 26.99	150.48 to 157.48	25.88 to 27.18	150.58 to 157.28	21.58 to 25.88	162.08 to 158.58
7-4	19	51	104.34	0.51	104.85	P	15.24 to 16.24	149.10 to 148.10	15.08 to 16.46	149.34 to 147.88	11.58 to 15.88	172.04 to 169.34
7-5	19	51	104.29	0.59	104.88	S	1.49 to 5.49	182.88 to 178.88	0.91 to 5.79	183.38 to 178.58	0.41 to 8.91	183.48 to 183.58
8-1	52	96	104.99	0.29	105.28	P	36.49 to 39.47	148.53 to 145.52	36.38 to 39.47	148.69 to 145.52	29.88 to 36.38	155.99 to 148.69
8-2	19	51	104.92	0.78	105.70	P	32.88 to 33.28	152.92 to 151.72	32.88 to 33.58	152.92 to 151.42	29.88 to 32.88	155.92 to 152.92
8-3	19	51	104.88	0.63	105.51	P	25.83 to 26.83	159.85 to 158.85	25.58 to 27.13	159.38 to 157.75	22.58 to 25.58	162.38 to 159.38
8-4	19	51	104.88	0.68	105.56	P	15.16 to 16.16	169.72 to 168.72	14.88 to 16.46	170.88 to 168.48	11.88 to 14.88	173.88 to 170.88
8-5	19	51	104.97	0.82	105.79	P	1.49 to 5.49	189.48 to 179.48	1.25 to 5.79	183.72 to 179.18	1.88 to 1.25	183.97 to 183.72
8-6		102	104.98	0.42	105.40	H	25.91	159.87	25.25 to 25.91	159.78 to 159.87	22.25 to 25.25	162.78 to 159.78
8-7		102	105.04	0.56	105.60	H	16.76	168.29	16.88 to 16.76	169.04 to 168.28	13.88 to 16.88	172.04 to 169.04
8-8	52	102	105.98	0.56	106.54	P	24.66 to 25.38	168.42 to 159.73	none-filter cloth around screen	none-filter cloth around screen	21.88 to 24.66	164.88 to 169.42
8-9	52	102	105.10	0.55	105.65	P	15.18 to 15.71	178.88 to 169.39	none-filter cloth around screen	none-filter cloth around screen	11.88 to 15.18	174.18 to 178.88
8-10	52	203	105.13	0.59	105.72	S	2.43 to 5.33	188.78 to 179.88	2.13 to 5.48	183.88 to 179.65	1.33 to 2.13	183.88 to 183.88
8-11	19	51	104.93	0.68	105.61	P	8.45 to 9.45	176.48 to 175.48	8.25 to 9.75	176.68 to 175.18	5.25 to 8.25	179.68 to 176.68
9-1	47	96	103.85	0.55	104.40	P	35.85 to 36.85	148.88 to 147.88	34.58 to 37.25	149.35 to 146.58	28.58 to 34.58	155.95 to 149.15
9-2	19	51	103.89	0.48	104.37	P	32.48 to 33.48	151.29 to 150.29	32.88 to 33.78	151.89 to 150.19	28.58 to 32.88	155.89 to 151.89
9-3	19	51	103.98	0.52	104.50	P	25.98 to 26.98	150.88 to 157.88	25.48 to 27.18	150.38 to 156.88	21.88 to 25.48	162.98 to 158.38

(P)-PIEZOMETER (S)-STANDPIPE (H)-PNEUMATIC PIEZOMETER (W)-WELL
(#)-BOREHOLE DIAMETER OPPOSITE SCREENED INTERVAL

Note: Stickup and top-of-monitor elevation for pneumatic piezometer are relative to top of protective casing

Table FI-1 Cont.
Ground Water Monitor Details

F-6

MONITOR NO.	MONITOR INSIDE DIAMETER (in)	BOREHOLE DIAMETER (in)	GROUND ELEVATION (to A.S.L.)	STICK UP (ft)	TOP OF MONITOR (to A.S.L.)	MONITOR TYPE	SCREENED INTERVAL		SAND PACK		SEAL	
							DEPTH FROM GRADE (ft)	ELEVATION (to A.S.L.)	DEPTH FROM GRADE (ft)	ELEVATION (to A.S.L.)	DEPTH FROM GRADE (ft)	ELEVATION (to A.S.L.)
9-4	19	31	182.89	0.52	184.41	P	15.24 to 16.24	168.65 to 167.65	15.00 to 16.40	168.89 to 167.43	11.50 to 15.00	172.39 to 168.89
9-5	19	31	183.86	0.45	184.31	S	1.49 to 5.49	182.37 to 178.37	0.81 to 5.79	182.05 to 178.07	0.45 to 0.81	183.41 to 183.05
10-1	32	96	183.92	0.61	184.53	P	34.83 to 39.83	147.07 to 144.07	34.78 to 40.00	147.22 to 143.92	25.00 to 34.78	158.92 to 147.22
10-2	19	31	184.93	0.47	184.50	P	32.28 to 33.28	151.83 to 150.83	31.68 to 33.50	152.43 to 150.53	20.00 to 31.68	155.73 to 152.40
10-3	19	31	183.94	0.59	184.53	P	25.98 to 26.98	150.84 to 157.84	25.30 to 27.10	158.64 to 154.84	21.00 to 25.30	162.94 to 158.64
10-4	19	31	184.03	0.58	184.61	P	15.24 to 16.24	168.77 to 167.77	14.68 to 16.40	169.43 to 167.57	10.90 to 14.68	173.13 to 169.43
10-5	19	31	183.99	0.79	184.78	S	1.49 to 5.49	182.50 to 178.50	0.91 to 5.79	183.08 to 178.28	0.60 to 0.91	183.39 to 183.09
10-6		182	183.90	0.71	184.61	N	27.18	156.89	26.18 to 27.18	157.89 to 156.89	22.00 to 26.18	161.99 to 157.89
10-7		182	183.92	0.67	184.59	N	16.40	167.40	15.60 to 16.40	168.32 to 167.40	11.00 to 15.60	172.52 to 168.32
10-8	32	182	184.04	0.30	184.42	P	24.48 to 25.00	159.64 to 159.04	none-filter cloth area and screen	none-filter cloth area and screen	20.00 to 24.48	164.04 to 159.64
10-9	32	182	184.46	0.34	184.80	P	14.85 to 15.45	169.61 to 169.01	none-filter cloth area and screen	none-filter cloth area and screen	9.00 to 14.85	175.46 to 169.61
10-10	32	76	184.01	0.47	184.48	S	2.85 to 3.44	181.16 to 180.55	2.85 to 3.44	181.16 to 180.35	1.50 to 2.85	182.51 to 181.16
10-11	19	31	184.91	0.60	184.61	P	8.52 to 9.53	175.40 to 174.40	8.45 to 9.75	175.56 to 174.26	4.50 to 8.45	179.51 to 175.56
10-12	19	182	183.74	1.00	184.74	P	14.78 to 15.78	169.84 to 168.84	14.28 to 15.90	169.54 to 167.84	12.78 to 14.28	171.84 to 169.54
11-1	47	96	184.34	0.62	184.96	P	40.47 to 41.45	143.07 to 142.09	39.99 to 41.50	144.35 to 142.84	32.30 to 39.99	152.84 to 144.35
11-2	19	31	184.42	0.67	185.09	P	34.00 to 35.00	150.34 to 149.42	33.69 to 35.10	150.82 to 149.32	30.50 to 33.69	153.92 to 150.82
11-3	19	31	184.41	0.59	185.00	P	27.44 to 28.35	156.97 to 156.06	26.52 to 28.65	157.89 to 155.76	23.40 to 26.52	161.01 to 157.89
11-4	19	31	184.33	0.59	184.94	P	16.78 to 17.78	167.57 to 166.65	16.40 to 18.00	167.99 to 166.35	10.00 to 16.40	171.83 to 167.93

(PI)-PIEZOMETER (SI)-STAMPPIPE (RI)-PNEUMATIC PIEZOMETER (WI)-WELL
(BI)-BOREHOLE DIAMETER OPPOSITE SCREENED INTERVAL

Note: Stickup and top-of-monitor elevation for pneumatic piezometer are relative to top of protective casing.

Table F1-1 Cont.
Ground Water Monitor Details

MONITOR NO	MONITOR INSIDE DIAMETER (in)	BOREHOLE DIAMETER (in)	GROUND ELEVATION (in A S L)	STICK UP (in)	TOP OF MONITOR (in A S L)	MONITOR TYPE	SCREENED INTERVAL		SAND PACK		SEAL	
							DEPTH FROM GRADE (in)	ELEVATION (in A S L)	DEPTH FROM GRADE (in)	ELEVATION (in A S L)	DEPTH FROM GRADE (in)	ELEVATION (in A S L)
11-5	19	51	184 35	0 38	184 93	S	1 40 to 5 49	182 75 to 178 04	0 90 to 5 79	183 45 to 178 56	0 78 to 0 98	183 65 to 183 45
12-1	52	96	184 07	0 55	184 62	P	38 00 to 41 00	146 07 to 143 07	38 00 to 41 20	146 07 to 142 07	38 00 to 38 00	154 07 to 146 07
12-2	19	51	183 98	0 49	184 47	P	35 38 to 36 30	140 68 to 147 60	35 00 to 36 60	140 98 to 147 30	31 00 to 35 00	152 98 to 140 98
12-3	19	51	184 18	0 60	184 78	P	25 90 to 26 80	150 20 to 157 30	25 30 to 27 10	150 00 to 157 00	22 13 to 25 30	162 05 to 158 00
12-4	19	51	184 03	0 67	184 70	P	16 00 to 17 78	167 23 to 166 33	16 20 to 18 50	167 03 to 166 03	13 30 to 16 29	179 73 to 167 03
12-5	19	51	183 96	0 65	184 61	S	1 40 to 5 49	182 36 to 178 47	0 91 to 5 79	183 05 to 178 17	0 71 to 0 91	183 25 to 183 05
12-6		102	184 22	0 69	184 91	H	27 10	157 12	26 40 to 27 10	157 02 to 157 12	25 00 to 26 50	161 22 to 157 72
12-7		102	184 11	0 53	184 64	H	17 30	166 01	16 40 to 17 60	167 71 to 166 51	13 00 to 16 40	171 11 to 167 71
12-8	52	102	183 77	0 61	184 38	P	24 55 to 25 15	159 22 to 158 62	none-filter cloth around screen	none-filter cloth around screen	20 00 to 24 30	163 77 to 159 39
12-9	52	102	183 70	0 55	184 25	P	15 25 to 15 85	160 45 to 167 05	none-filter cloth around screen	none-filter cloth around screen	10 00 to 15 25	173 70 to 160 45
12-10	52	203	183 64	0 52	184 16	S	2 30 to 5 33	181 34 to 178 31	2 00 to 5 33	181 64 to 178 31	1 00 to 2 00	182 64 to 181 64
12-11	19	51	183 99	0 70	184 69	P	8 55 to 9 45	175 44 to 174 54	8 30 to 9 75	175 69 to 174 24	4 76 to 8 30	179 29 to 175 69
12-12a		89	184 11	1 09	185 20	H	71 10	113 01	70 00 to 71 30	114 11 to 112 01	50 00 to 70 00 and 71 30 to 72 30	133 31 to 114 11 and 112 01 to 111 01
12-12b		89	184 11	1 09	185 20	H	50 50	133 61	49 00 to 50 00	134 31 to 133 31	40 00 to 49 00	144 11 to 134 31
12-12c	52	96	184 19	0 93	185 12	P	38 90 to 39 90	145 29 to 144 29	38 50 to 40 00	145 69 to 144 19	36 00 to 38 50	148 19 to 145 69
12-13	52	100	183 56	0 47	184 03	P	1 20 to 1 50	182 36 to 182 06	1 15 to 1 52	182 41 to 182 04	0 00 to 1 15	183 56 to 182 41
12-14	52	100	183 59	0 55	184 14	P	2 20 to 2 50	181 39 to 181 09	2 00 to 2 50	181 59 to 181 09	0 00 to 2 00	183 59 to 181 59
12-15	52	100	183 52	0 62	184 14	P	2 70 to 3 00	180 02 to 180 52	2 60 to 3 00	180 92 to 180 52	0 00 to 2 60	183 52 to 180 92

(P)-PIEZOMETER (S)-STANDPIPE (H)-PRESSURATIC PIEZOMETER (W)-WELL
(in)-BOREHOLE DIAMETER OPPOSITE SCREENED INTERVAL

Note: Stickup and top-of monitor elevation for pneumatic piezometers are relative to top of protective casing

Table F1-1 Cont.
Ground Water Monitor Details

MONITOR NO	MONITOR INSIDE DIAMETER (in)	BOREHOLE DIAMETER (in)	GROUND ELEVATION (ft A S L)	STICK UP (ft)	TOP OF MONITOR (ft A S L)	MONITOR TYPE	SCREENED INTERVAL		SAND PACK		SEAL	
							DEPTH FROM GRADE (ft)	ELEVATION (ft A S L)	DEPTH FROM GRADE (ft)	ELEVATION (ft A S L)	DEPTH FROM GRADE (ft)	ELEVATION (ft A S L)
12-16	52	108	183.57	0.61	184.18	P	3.78 to 4.00	179.87 to 179.57	3.60 to 4.00	179.97 to 179.57	0.00 to 3.60	183.57 to 179.97
12-17	52	108	183.62	0.57	184.19	P	4.50 to 4.00	179.12 to 178.82	4.48 to 4.00	179.22 to 178.82	0.00 to 4.48	183.62 to 179.22
12-18	52	108	183.68	0.59	184.27	P	5.20 to 5.50	178.48 to 178.18	5.18 to 5.50	178.58 to 178.18	0.00 to 5.18	183.68 to 178.58
12-19	52	108	183.73	0.63	184.36	P	6.00 to 6.30	177.73 to 177.43	5.98 to 6.30	177.83 to 177.43	0.00 to 5.98	183.73 to 177.83
12-20	52	108	183.82	0.52	184.34	P	6.70 to 7.00	177.12 to 176.82	6.68 to 7.00	177.22 to 176.82	0.00 to 6.68	183.82 to 177.22
12-21	52	108	183.97	0.52	184.49	P	7.70 to 8.00	176.27 to 175.97	7.68 to 8.00	176.37 to 175.97	0.00 to 7.68	183.97 to 176.37
12-22	96	159	184.22	0.54	184.76	M	39.00 to 41.00	145.22 to 143.22	24.00 to 37.00 to 38.38	160.22 to 149.22 to 147.22 to 145.92	24.00 to 38.38	160.22 to 145.92
13-1	47	96	185.05	0.67	185.72	P	39.70 to 40.70	145.35 to 144.35	38.18 to 40.85	146.95 to 144.28	33.00 to 38.18	152.05 to 146.95
13-2	19	51	185.14	0.62	185.76	S	1.49 to 5.49	183.65 to 179.65	0.91 to 5.79	184.23 to 179.35	0.60 to 0.91	184.54 to 184.23
14-1	47	96	181.65	0.56	182.21	P	41.68 to 42.68	140.95 to 139.95	39.98 to 42.66	141.75 to 138.99	31.00 to 39.99	150.65 to 141.66
14-2	19	51	181.62	0.59	182.21	S	1.49 to 5.49	180.13 to 176.13	0.90 to 5.79	180.72 to 175.83	0.60 to 0.90	181.02 to 180.72
15-1	47	96	182.75	0.64	183.39	P	38.50 to 39.50	144.25 to 143.25	37.68 to 40.34	145.13 to 142.41	32.00 to 37.68	150.75 to 145.15
15-2	19	51	182.74	1.15	183.89	S	1.63 to 5.63	181.11 to 177.11	1.00 to 5.63	181.74 to 177.11	0.65 to 1.00	182.09 to 181.74
16-1	52	96	185.95	0.51	186.46	P	29.08 to 30.08	156.15 to 155.15	27.88 to 30.88	158.15 to 155.15	20.78 to 27.88	165.25 to 158.15
16-2	19	51	186.89	0.60	187.49	S	1.88 to 5.88	184.29 to 180.29	1.88 to 5.88	185.89 to 180.29	0.75 to 1.88	185.34 to 185.09

(P)-PIEZOMETER (S)-STANDPIPE (M)-PNEUMATIC PIEZOMETER (W)-WELL
(B)-BOREHOLE DIAMETER OPPOSITE SCREENED INTERVAL

Note: Stickup and top-of monitor elevation for pneumatic piezometers are relative to top of protective casing

F2 WATER LEVEL DATA

Water levels are monitored on a regular ongoing basis at all installations. The techniques used for measuring water levels are described in Appendix A3. Initially, water level readings were recorded on a daily basis following the installation of each monitor. As each monitor filled with water and eventually approached anticipated static conditions, monitoring frequency was decreased. All daily monitoring was suspended at the end of the drilling program (approximately March 7, 1986) even though some of the later installations had not reached static conditions. Water levels were measured during March and April only when staff were available on-site.

Water levels were measured on a monthly basis over the period April to October, 1986. The long-term water level measurement program serves to: (a) confirm static levels, and (b) record seasonal fluctuations.

Table F2-1 presents all water level measurements, both during and after the drilling program. All values are in metres above mean sea level (m ASL). Also shown for reference are top-of-pipe elevation, ground elevation, and screened interval elevations for each monitor.

DRILLING LOCATION 85-1

[illegible]

TABLE F2-1 WATER LEVEL DATA

DRILLING LOCATION 85-7

FORMATION	85-7-1	85-7-2	85-7-3	85-7-4	85-7-5
TOP OF PIPE ELEVATION	184.99	184.91	184.84	184.85	184.88
GROUND ELEVATION	184.37	184.39	184.38	184.34	184.29
SCREENED INTERVAL	144.74	150.49	158.48	169.18	182.88
17-Jan-84	176.44				
20-Jan-84	176.44				
21-Jan-84	176.44				
22-Jan-84	176.44				
23-Jan-84	176.44				
24-Jan-84	176.44				
25-Jan-84	176.44				
26-Jan-84	176.44				
27-Jan-84	176.44				
28-Jan-84	176.44				
29-Jan-84	176.44				
30-Jan-84	176.44				
31-Jan-84	176.44				
1-Feb-84	176.44				
2-Feb-84	176.44				
3-Feb-84	176.44				
4-Feb-84	176.44				
5-Feb-84	176.44				
6-Feb-84	176.44				
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26-Feb-84	176.44				
27-Feb-84	176.44				
28-Feb-84	176.44				
29-Feb-84	176.44				
30-Feb-84	176.44				
31-Feb-84	176.44				
1-Mar-84	176.44				
2-Mar-84	176.44				
3-Mar-84	176.44				
4-Mar-84	176.44				
5-Mar-84	176.44				
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28-Mar-84	176.44				
29-Mar-84	176.44				
30-Mar-84	176.44				
31-Mar-84	176.44				
1-Apr-84	176.44				
2-Apr-84	176.44				
3-Apr-84	176.44				
4-Apr-84	176.44				
5-Apr-84	176.44				
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27-Apr-84	176.44				
28-Apr-84	176.44				
29-Apr-84	176.44				
30-Apr-84	176.44				
31-Apr-84	176.44				
1-May-84	176.44				
2-May-84	176.44				
3-May-84	176.44				
4-May-84	176.44				
5-May-84	176.44				
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28-May-84	176.44				
29-May-84	176.44				
30-May-84	176.44				
31-May-84	176.44				
1-Jun-84	176.44				
2-Jun-84	176.44				
3-Jun-84	176.44				
4-Jun-84	176.44				
5-Jun-84	176.44				
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28-Jun-84	176.44				
29-Jun-84	176.44				
30-Jun-84	176.44				
31-Jun-84	176.44				
1-Jul-84	176.44				
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31-Jul-84	176.44				
1-Aug-84	176.44				
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28-Aug-84	176.44				
29-Aug-84	176.44				
30-Aug-84	176.44				
31-Aug-84	176.44				
1-Sep-84	176.44				
2-Sep-84	176.44				
3-Sep-84	176.44				
4-Sep-84	176.44				
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30-Sep-84	176.44				
31-Sep-84	176.44				
1-Oct-84	176.44				
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10-Oct-84	176.44				
11-Oct-84	176.44				
12-Oct-84	176.44				
13-Oct-84	176.44				
14-Oct-84	176				

DRILLING LOCATION 85-9

POSITION #	85-1-1	85-1-2	85-1-3	85-1-4	85-1-5	85-1-6	85-1-7	85-1-8	85-1-9	85-1-10	85-1-11
TOP OF TYPE ELEVATION	184.40	184.49	184.42	184.41	184.38	184.31	184.24	184.17	184.10	184.03	183.96
CORRECTION ELEVATION	183.85	183.89	183.94	183.89	183.84	183.77	183.70	183.63	183.56	183.49	183.42
SCHEDULED INTERVAL	140.00	131.29	138.00	140.43	142.87	145.31	147.75	150.19	152.63	155.07	157.51
85-1-1	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-2	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-3	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-4	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-5	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-6	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-7	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-8	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-9	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-10	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23
85-1-11	176.11	176.11	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23	176.23

DRILLING LOCATION 85-8

POSITION #	85-1-1	85-1-2	85-1-3	85-1-4	85-1-5	85-1-6	85-1-7	85-1-8	85-1-9	85-1-10	85-1-11
TOP OF TYPE ELEVATION	183.28	183.28	183.28	183.28	183.28	183.28	183.28	183.28	183.28	183.28	183.28
CORRECTION ELEVATION	184.99	184.92	184.88	184.80	184.77	184.69	184.64	184.58	184.51	184.44	184.37
SCHEDULED INTERVAL	140.34	135.92	136.03	136.72	137.40	138.08	138.76	139.44	140.12	140.80	141.48
85-1-1	176.38	176.38	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-2	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-3	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-4	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-5	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-6	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-7	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-8	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-9	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-10	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41
85-1-11	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41	176.41

TABLE F2-1 (cont.)

DRILLING LOCATION 85-10

[illegible]

DRILLING LOCATION 85-11

[illegible]

TABLE F2-1 (cont.)

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	
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G-1

APPENDIX G

HYDROGEOLOGIC TEST RESULTS

APPENDIX G
HYDROGEOLOGIC TEST RESULTS
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G1 MONITOR RECOVERY ANALYSIS

Hydraulic conductivity values were determined for many monitors using water level recovery data. A discussion of the methodology and monitor recovery analysis results follows.

G1.1 DATA COLLECTION AND ANALYSIS

Ground water monitors were generally installed in boreholes that were dry or nearly dry. By measuring water levels daily, immediately after installation, it was possible to determine the rate at which the monitors recovered to static levels.

Water level recovery in many of the monitors, particularly those in the unweathered silt and clay, was sufficiently slow to permit the analysis of the daily water level measurement data to provide hydraulic conductivity values. The analysis is based on the method of Hvorslev (1951). The Hvorslev method was originally developed for slug test analysis. However, the recovery of a monitor from dry or nearly dry is equivalent to the withdrawal of a "slug" of water, which is the method used for slug testing.

Figure G1-1 shows the input for a typical example, which includes the observed water levels, and Figure G1-2 presents the data plot, line fitting, and calculations that result in a value of hydraulic conductivity (K) for the unit in which the monitor sand pack is located. Copies of all monitor recovery analyses are contained in an open file report provided to OWMC.

G-5

Example Of Typical Monitor Recovery Data

HVORSLEV'S METHOD

Figure G1-1

PROJECT NAME: OWMC
 PROJECT NUMBER: 85-6H-9
 INSTALLATION ID: 85-8-4
 TEST START DATE: 14 JAN 1986
 TEST START TIME: 14:00:00
 STATIC WATER LEVEL H (mbRP): 4.4
 INITIAL WATER LEVEL H₀ (mbRP): 15.01

DATE	ACTUAL TIME	CUMULATIVE TIME (hours)	WATER LEVEL (mbRP)	$\frac{H-h}{H-H_0}$
15 JAN 1986	08:00:00	18.00	14.09	.91
16 JAN 1986	09:00:00	43.00	12.98	.81
17 JAN 1986	08:00:00	66.00	12.08	.72
20 JAN 1986	15:00:00	145.00	9.68	.50
21 JAN 1986	13:30:00	167.50	9.26	.46
22 JAN 1986	16:30:00	194.50	8.70	.41
24 JAN 1986	08:00:00	234.00	8.01	.34
27 JAN 1986	15:00:00	313.00	6.96	.24
28 JAN 1986	14:30:00	336.50	6.70	.22
29 JAN 1986	16:00:00	362.00	6.50	.20
30 JAN 1986	14:30:00	384.50	6.33	.18
31 JAN 1986	08:00:00	402.00	6.20	.17
03 FEB 1986	16:00:00	482.00	5.73	.13
05 FEB 1986	10:45:00	524.75	5.51	.10
07 FEB 1986	08:00:00	570.00	5.34	.09
10 FEB 1986	10:30:00	644.50	5.13	.07
11 FEB 1986	11:00:00	669.00	5.06	.06
12 FEB 1986	11:15:00	693.25	5.01	.06
13 FEB 1986	14:50:00	720.83	4.96	.05
14 FEB 1986	08:30:00	738.50	4.90	.05
17 FEB 1986	14:00:00	816.00	4.75	.03
18 FEB 1986	17:00:00	843.00	4.73	.03
19 FEB 1986	15:00:00	865.00	4.68	.03
20 FEB 1986	10:00:00	884.00	4.72	.03
24 FEB 1986	14:00:00	984.00	4.63	.02
25 FEB 1986	14:45:00	1008.75	4.62	.02
26 FEB 1986	15:15:00	1033.25	4.58	.02
27 FEB 1986	14:20:00	1056.33	4.56	.02
28 FEB 1986	09:45:00	1075.75	4.56	.02
03 MAR 1986	11:50:00	1149.83	4.51	.01
04 MAR 1986	14:15:00	1176.25	4.49	.01
05 MAR 1986	10:30:00	1196.50	4.50	.01
06 MAR 1986	14:05:00	1224.08	4.48	.01
07 MAR 1986	09:00:00	1243.00	4.49	.01
11 MAR 1986	10:30:00	1340.50	4.44	0.00

NOTE - mbRP is metres below Reference Point elevation
 - h is reading in mbRP

ANALYSIS - HVORSLEV'S METHOD

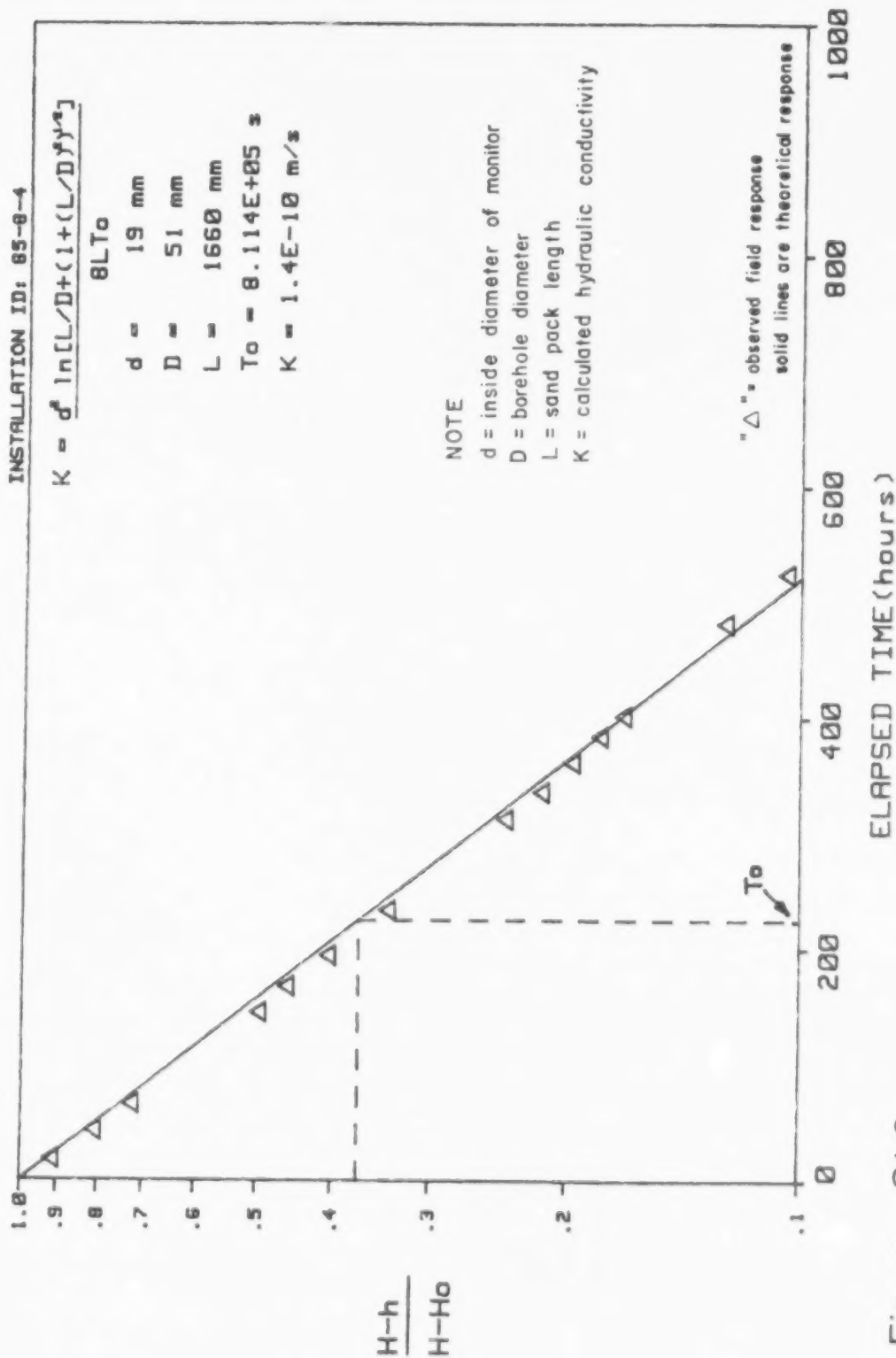


Figure G1-2
 Example Analysis Of Monitor Recovery Data

G1.2 RESULTS

The results of all recovery analyses are summarized in Table G1-1. The table lists the calculated value of hydraulic conductivity (K) in metres per second (m/s) for each monitor for which the recovery data was suitable for analysis. Also shown is the range of elevation that the test result represents (i.e. the sand pack interval).

TABLE G1-1: VALUES OF HYDRAULIC CONDUCTIVITY
DETERMINED BY RECOVERY ANALYSIS

BOREHOLE	ELEVATION TESTED (m ASL)	HYDRAULIC CONDUCTIVITY K (m/s)
UNWEATHERED SILT AND CLAY		
85-1-4	170.04 - 169.04	1E-10
85-2-4	169.53 - 168.43	9E-11
85-3-4	170.14 - 169.22	8E-11
85-4-4	170.18 - 169.28	1E-10
85-5-4	168.56 - 167.56	1E-10
85-6-4	170.09 - 169.09	8E-11
85-7-4	169.10 - 168.10	2E-10
85-8-4	169.72 - 168.72	1E-10
85-9-4	168.65 - 167.65	1E-10
85-10-4	168.79 - 167.79	1E-10
85-11-4	167.57 - 166.65	1E-10
85-12-4	167.23 - 166.33	2E-10
85-1-3	159.41 - 158.41	1E-10
85-2-3	159.24 - 158.04	1E-10
85-3-3	159.42 - 158.50	2E-10
85-4-3	159.48 - 158.58	2E-10
85-5-3	159.60 - 158.60	2E-10
85-6-3	159.26 - 158.26	1E-10
85-7-3	158.48 - 157.48	2E-10
85-8-3	158.05 - 157.05	1E-10
85-9-3	158.00 - 157.00	2E-10
85-10-3	158.04 - 157.04	2E-10
85-11-3	156.97 - 156.06	2E-10
85-12-3	158.28 - 157.38	2E-10
LOWER TILL		
85-7-2	150.49 - 149.49	4E-10
85-8-2	152.92 - 151.72	3E-10

G2 SLUG TESTING

Slug testing involves displacing water in a monitor and measuring the rate at which the water levels recover to static. The pattern of the water level recovery can be analysed to provide an estimate of hydraulic conductivity. A discussion of the slug testing program at the Preferred Site follows.

G2.1 DATA COLLECTION AND ANALYSIS

The techniques used to perform and collect data for the slug tests are outlined in Appendix A3. Slug tests were attempted at all monitors other than those designated for geochemical sampling.

The pattern of response obtained from several of the monitors did not allow for interpretation using the analysis technique discussed below. These monitors were: 85-1-5, 85-2-4, 85-3-2, 85-3-5, 85-4-2, 85-6-3, 85-6-4, 85-6-5, and 85-10-4. Each of these monitors was tested more than once but no improvement in the data resulted. The reason for the atypical response is not known, but may be related to monitor construction -- for example joint leakage, seal leakage, or blockage by siltation.

Monitor 85-8-1 was not slug tested because property access was denied at the time of testing.

Most of the slug test data was analysed using the method described by Hvorslev (1951). Some of the bedrock monitors which were slug tested, namely those in very high permeability

formations, demonstrated an oscillatory response due to inertial effects in the monitor pipe. These tests were analysed using the method developed by van der Kamp (1976). Slug tests performed in standpipes were analysed using the method outlined by Bower and Rice (1976). Figure G2-1 shows typical slug test data collected during a field test. Figure G2-2 illustrates the analysis of the data using the Hvorslev method including calculations used to establish a value of hydraulic conductivity (K) for the formation in which the monitor sand pack is located. Copies of all slug test analyses were provided to OWMC and are contained in an open file report.

Two of the monitors completed in the Lower Till, 85-6-2 and 85-9-2, responded too quickly to measure a detailed water level response profile prior to reaching static level. However, it was possible to record the approximate time at which static water level was reached. This value was used to calculate a lower limit for hydraulic conductivity using the following two data points:

- (1) initial reading at a water level calculated by knowing the volume of the slug inserted or withdrawn,
- 2) reading at the time when "full" recovery was noted, which was taken to represent a water level that corresponds to 90% recovery (conservative estimate to provide lower limit of hydraulic conductivity).

G2.2 RESULTS

Table G2-1 summarizes the results of all slug test analyses. The table lists calculated hydraulic conductivities (K) in

SLUG TEST ANALYSIS

(HUORSLEU'S METHOD)

PROJECT NAME: OWMC
 PROJECT NUMBER: 85-GW-9
 INSTALLATION ID: 85-9-3
 TEST START DATE: 19 MAR 1986
 TEST START TIME: 08:54:00
 STATIC WATER LEVEL H (mbRP): 6.31
 INITIAL WATER LEVEL Ho (mbRP): 5.91

DATE	ACTUAL TIME	CUMULATIVE TIME (hours)	WATER LEVEL (mbRP)	$\frac{H-h}{H-H_o}$
20 MAR 1986	09:05:00	24.18	5.94	.92
20 MAR 1986	15:34:00	30.67	5.96	.88
21 MAR 1986	08:59:00	48.08	6.00	.78
24 MAR 1986	12:58:00	124.07	6.11	.50
24 MAR 1986	16:54:00	128.00	6.12	.48
25 MAR 1986	09:20:00	144.43	6.13	.45
25 MAR 1986	15:23:00	150.48	6.14	.42
26 MAR 1986	06:49:00	165.92	6.15	.40
31 MAR 1986	14:20:00	293.43	6.22	.23
01 APR 1986	08:42:00	311.80	6.23	.20
01 APR 1986	19:14:00	322.33	6.23	.20

NOTE - mbRP is metres below Reference Point elevation
 - h is reading in mbRP

Figure G2-1
 Example Of Typical Slug Test Data

SLUG TEST ANALYSIS - HVORSLEV'S METHOD

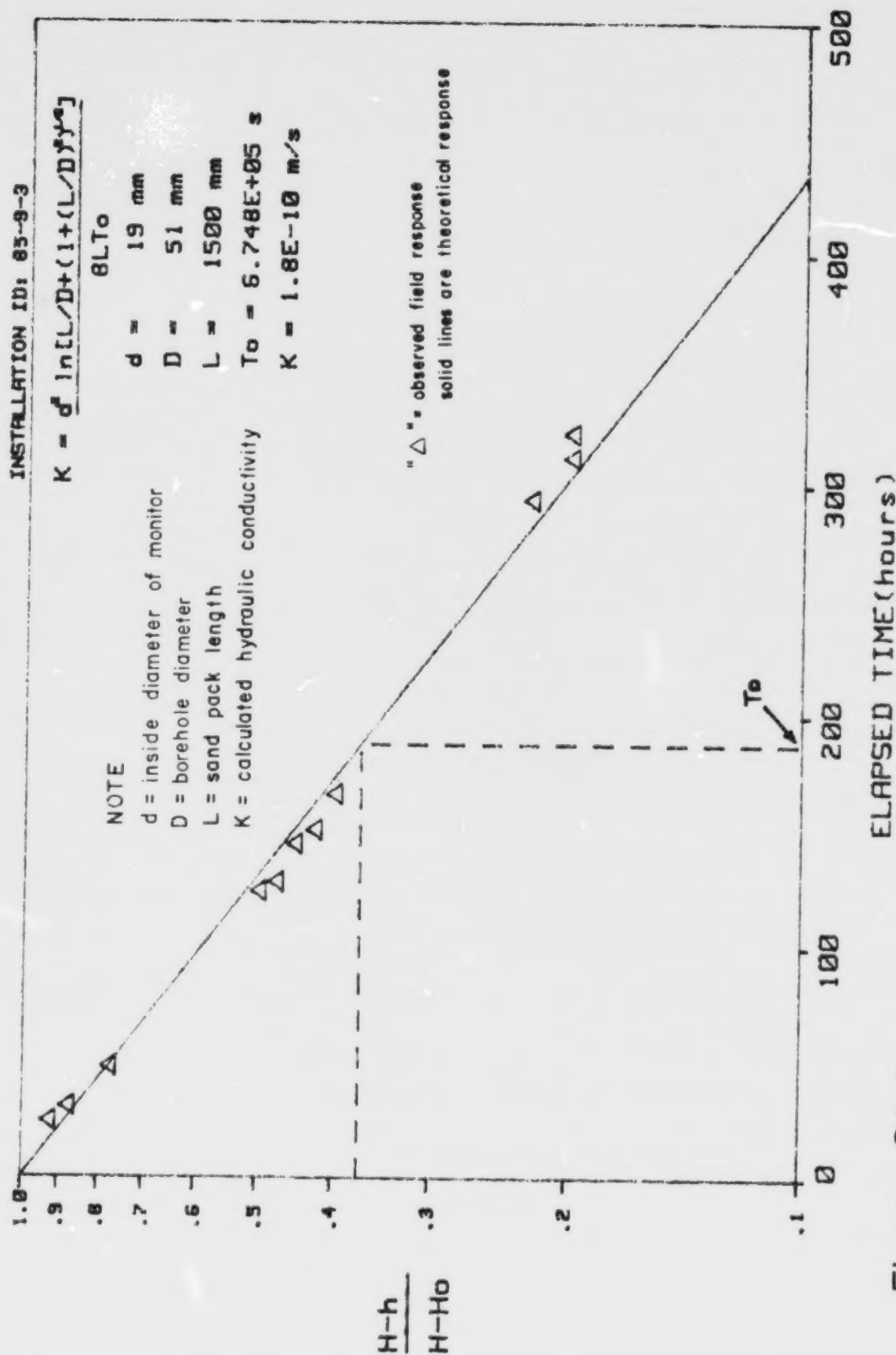


Figure G2-2
Example Analysis Of Slug Test Data

TABLE G2-1: VALUES OF HYDRAULIC CONDUCTIVITY
DETERMINED BY SLUG TEST ANALYSIS

BOREHOLE	ELEVATION TESTED (m ASL)	HYDRAULIC CONDUCTIVITY K (m/s)
WEATHERED SILT AND CLAY		
85-1-5 *		--
85-2-5	182.21 - 179.21	6E-9
85-3-5 *		--
85-4-5	183.71 - 179.82	4E-9
85-5-5	183.88 - 179.88	7E-7
85-6-5 *		--
85-7-5	182.80 - 178.80	2E-9
85-8-5	183.48 - 179.48	4E-9
85-9-5	182.37 - 178.37	5E-9
85-10-5	182.50 - 178.50	5E-7
85-11-5	182.75 - 178.86	6E-9
85-12-5	182.36 - 178.47	1E-8
85-13-2	183.65 - 179.65	2E-7
85-14-2	180.13 - 176.13	1E-8
85-15-2	181.11 - 177.11	4E-8
85-16-2	184.29 - 180.29	5E-7
UNWEATHERED SILT AND CLAY		
85-1-11	176.56 - 175.52	5E-10
85-3-11	176.73 - 175.73	2E-9
85-8-11	176.48 - 175.48	1E-9
85-10-11	175.48 - 174.48	2E-10
85-10-12	169.04 - 168.04	2E-9
85-12-11	175.44 - 174.54	2E-9
85-1-4	170.04 - 169.04	1E-10
85-2-4 *		--
85-3-4	170.14 - 169.22	2E-10
85-4-4	170.18 - 169.28	2E-10
85-5-4	168.56 - 167.56	1E-10
85-6-4 *		--
85-7-4	169.10 - 168.10	1E-10
85-8-4	169.72 - 168.72	1E-10
85-9-4	168.65 - 167.65	1E-10
85-10-4 *		--
85-11-4	167.57 - 166.65	3E-10
85-12-4	167.23 - 166.33	3E-10
85-1-3	159.41 - 158.41	8E-11
85-2-3	159.24 - 158.04	4E-10
85-3-3	159.42 - 158.50	4E-10
85-4-3	159.48 - 158.58	1E-10
85-5-3	159.60 - 158.60	2E-10

TABLE G2-1: continued...

BOREHOLE	ELEVATION TESTED (m ASL)	HYDRAULIC CONDUCTIVITY K (m/s)
UNWEATHERED SILT AND CLAY cont...		
85-6-3 *		--
85-7-3	158.48 - 157.48	8E-11
85-8-3	158.05 - 157.05	1E-10
85-9-3	158.00 - 157.00	2E-10
85-10-3	158.04 - 157.04	2E-10
85-11-3	156.97 - 156.06	3E-10
85-12-3	158.28 - 157.38	2E-10
LOWER TILL		
85-1-2	153.34 - 152.34	2E-8
85-2-2	153.23 - 152.23	6E-10
85-3-2 *		--
85-4-2 *		--
85-5-2	150.99 - 149.99	2E-9
85-6-2	151.92 - 150.92	>4E-5
85-7-2	150.49 - 149.49	7E-10
85-8-2	152.92 - 151.72	7E-10
85-9-2	151.29 - 150.29	>7E-5
85-10-2	151.83 - 150.83	7E-10
85-11-2	150.34 - 149.42	4E-8
85-12-2	148.68 - 147.68	7E-10
BEDROCK AQUIFER		
85-1-12	150.13 - 149.13	4E-3
85-2-1	149.57 - 148.05	2E-4
85-3-1	153.24 - 150.55	6E-5
85-4-1	148.23 - 147.25	8E-5
85-5-1	146.00 - 145.00	2E-4
85-6-1	148.24 - 146.72	3E-4
85-7-1	146.74 - 145.74	2E-5
85-8-1 **		--
85-9-1	148.00 - 147.00	2E-3
85-11-1	143.87 - 142.89	2E-4
85-12-1	146.07 - 143.07	2E-3
85-13-1	145.35 - 144.35	4E-5
85-14-1	140.05 - 139.05	1E-5
85-15-1	144.25 - 143.25	8E-5
85-16-1	156.15 - 155.15	6E-4

NOTES: " > " indicates estimated minimum value
 * atypical response, not analysed
 ** no property access, not tested

metres per second (m/s) for all monitors for which suitable data were obtained. Where more than one set of slug test data was analysed, the value reported in Table G2-1 is the geometric mean.

Also shown are the upper and lower elevations for the sand pack which was emplaced around the monitor screen. This range in elevation is considered to be the test interval.

G3 PACKER TESTING

Boreholes 85-1-12 and 85-12-12 were drilled 27 m and 33.4 m (respectively) into the bedrock. Packer equipment was used to seal off successive 3 m intervals of the bedrock in each hole. Testing was then performed to determine static hydraulic head, hydraulic conductivity, and storativity. The analysis techniques and results of the packer testing are presented in this section.

G3.1 DATA COLLECTION AND ANALYSIS

Packer testing was performed by Waterra Hydrogeology Inc. during February 1986. The data collection technique was described in Appendix A3.3.

The initial analysis of the packer test data was performed by Waterra Hydrogeology Inc. using the standard type-curve matching technique of Cooper et al (1967). While this technique is considered to give reasonable estimates of hydraulic conductivity, its authors point out that the calculations may result in unrealistic values of formation storativity (see Section G3.3).

Gartner Lee Limited have developed a computer model named "GLIMPSE" which simulates transient test response in homogeneous porous media. Use of this model permits simulation of stress induced during testing. A detailed description of the GLIMPSE model is provided in McLaren et al. (1985).

Selected test zones were re-analysed using the GLIMPSE model in the following manner. An initial simulation was performed using the value of hydraulic conductivity determined from the type-curve analysis but assigning a more reasonable storativity value ($3e-7$ to $3e-4$). The simulated response was then compared to the actual field response data. The hydraulic conductivity and storativity values were then further adjusted to more closely match the actual field response.

In some cases it was also necessary to include "skin effects" in the simulations, which accounts for disturbance of the test formation due to drilling and development. This was particularly relevant to zones of high hydraulic conductivity and zones whose calculated storativity was unrealistically low. Further discussions with regard to the skin effect may be found in McLaren et al. (1985).

Figures G3-1 to G3-6 illustrate each of the GLIMPSE analyses. In each case the actual field data is represented by the "x" symbols. Curve 1 on each plot is the simulation using the hydraulic conductivity calculated from the type-curve analysis, a storativity value of $4E-7$ (indicated by Freeze and Cherry, 1979, to be the lower limit for this type of formation), and not accounting for skin effects. Curve 3, where shown, illustrates a simulation whereby both hydraulic conductivity and storativity were adjusted to give the best possible match to the field data without accounting for skin effects. This was generally only applicable to lower permeability intervals. Curve 2 in each case shows the best possible match to the field data when hydraulic conductivity, storativity, and skin effects are adjusted in the simulation.

Figure G3-1
Glimpse Results For 85-1-12 Interval 1

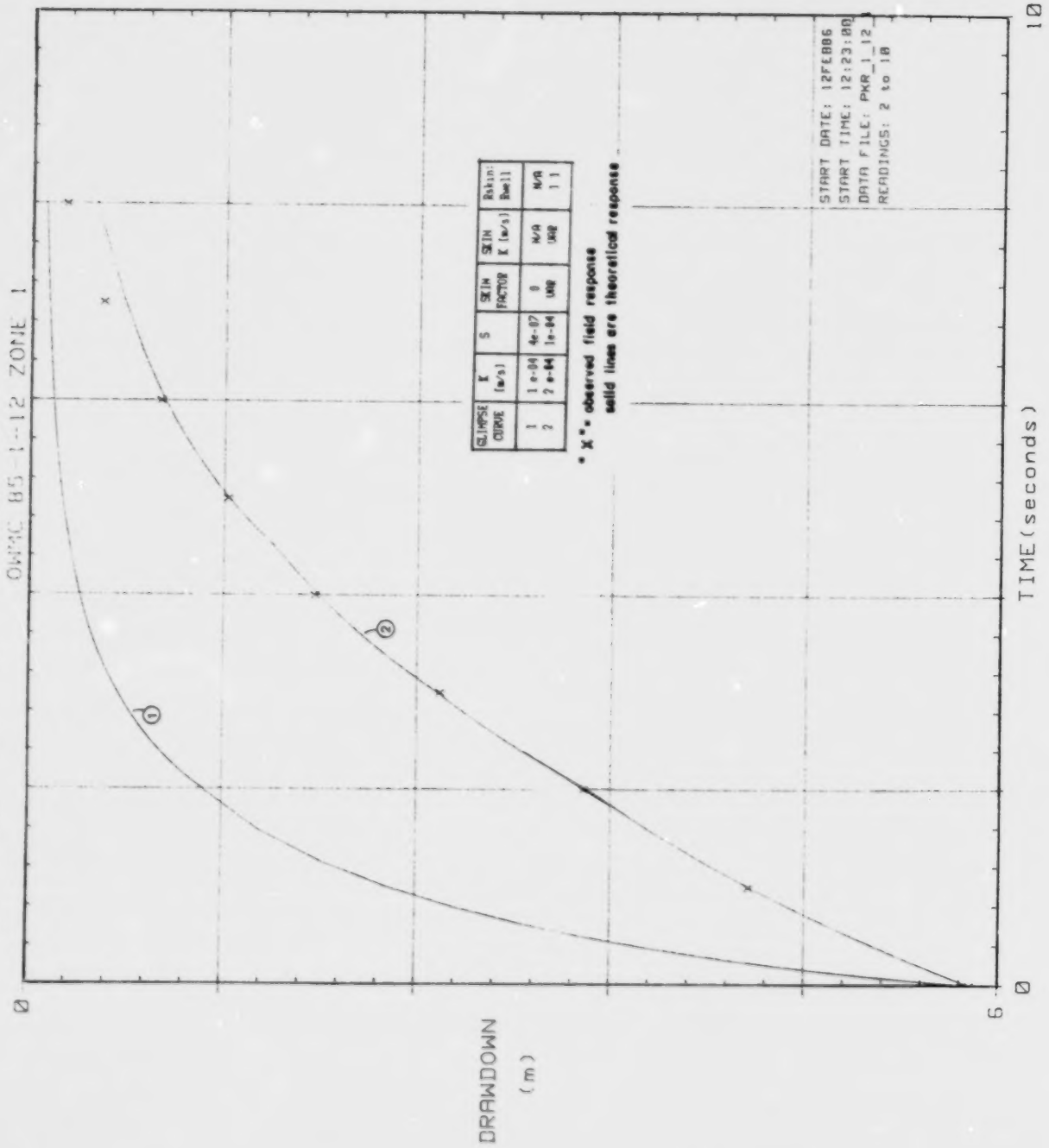


Figure G3-2
 Glimpse Results For 85-1-12 Interval 5

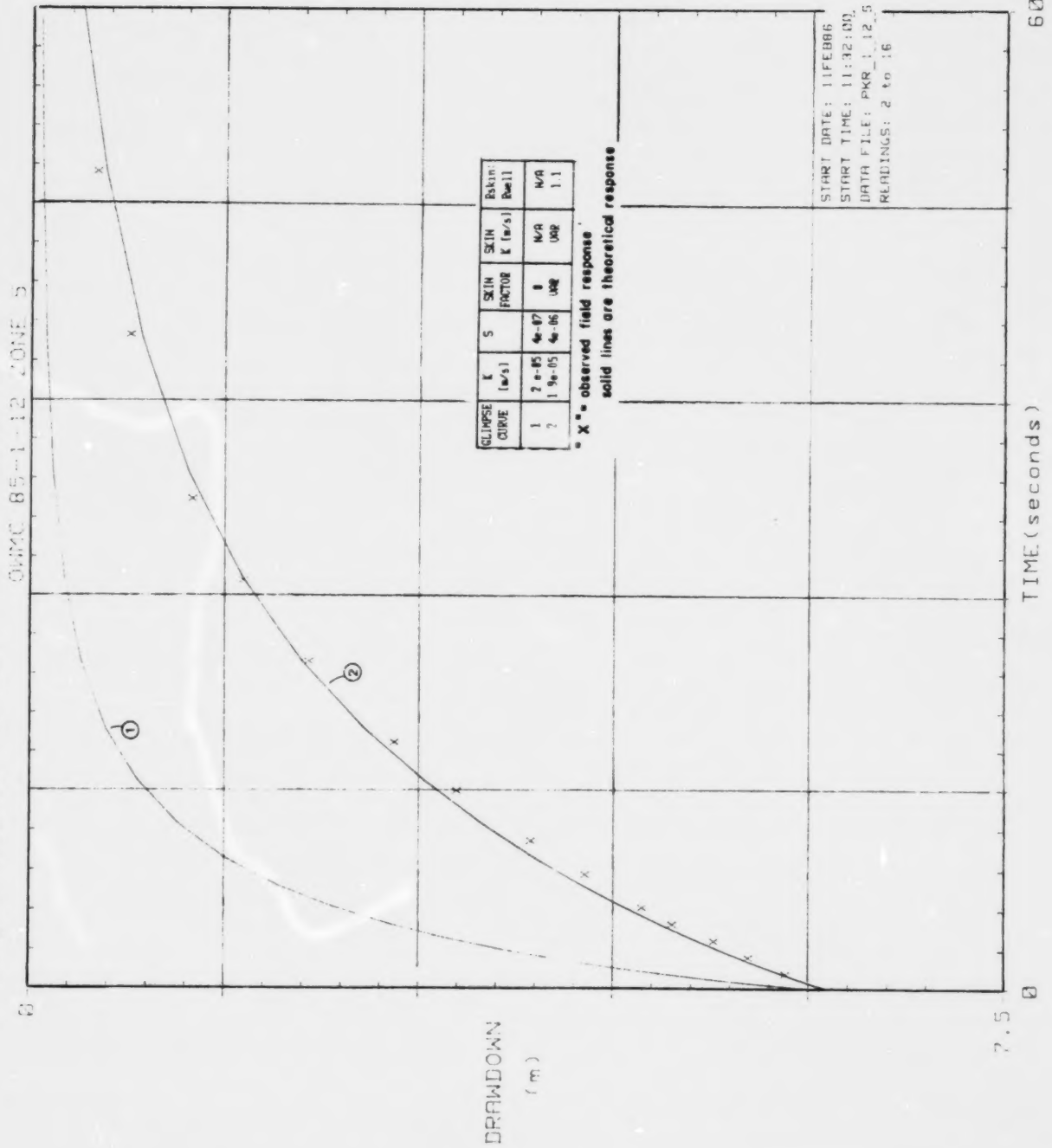


Figure G3-3
Glimpse Results For 85-1-12 Interval 9

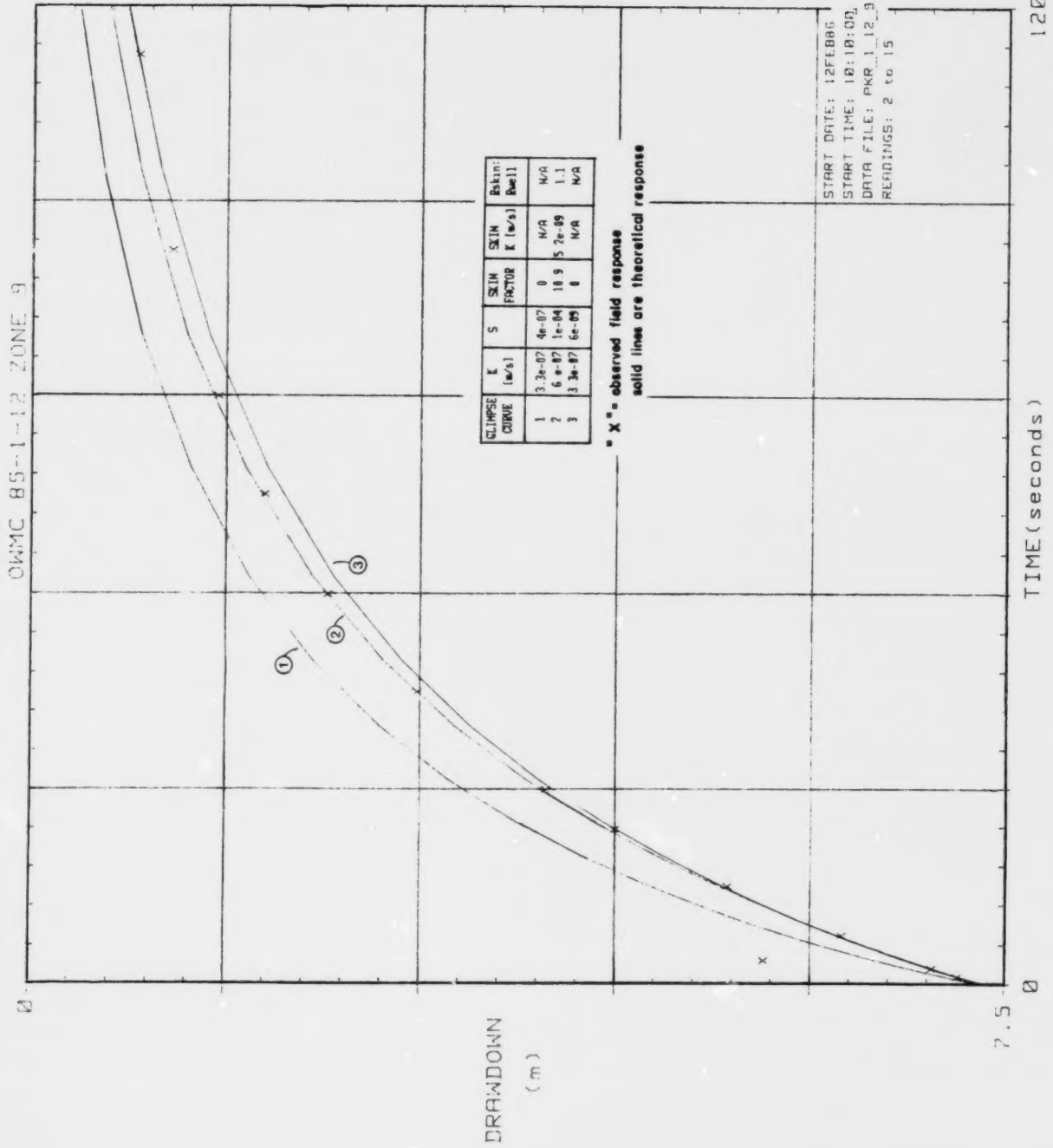


Figure G3-4
Glimpse Results For 85-12-12 Interval 1

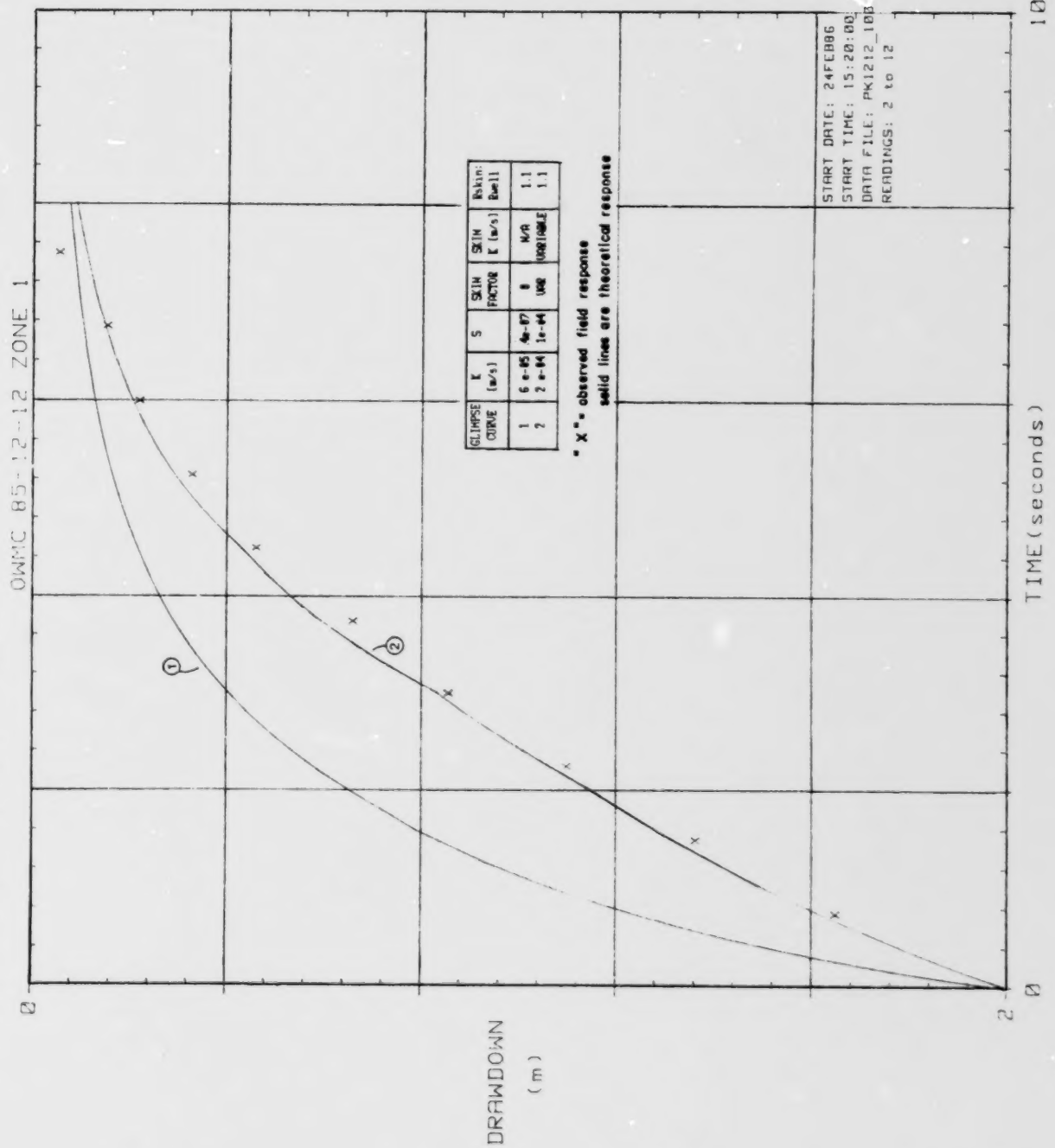


Figure G3-5
Glimpse Results For 85-12-12 Interval 2

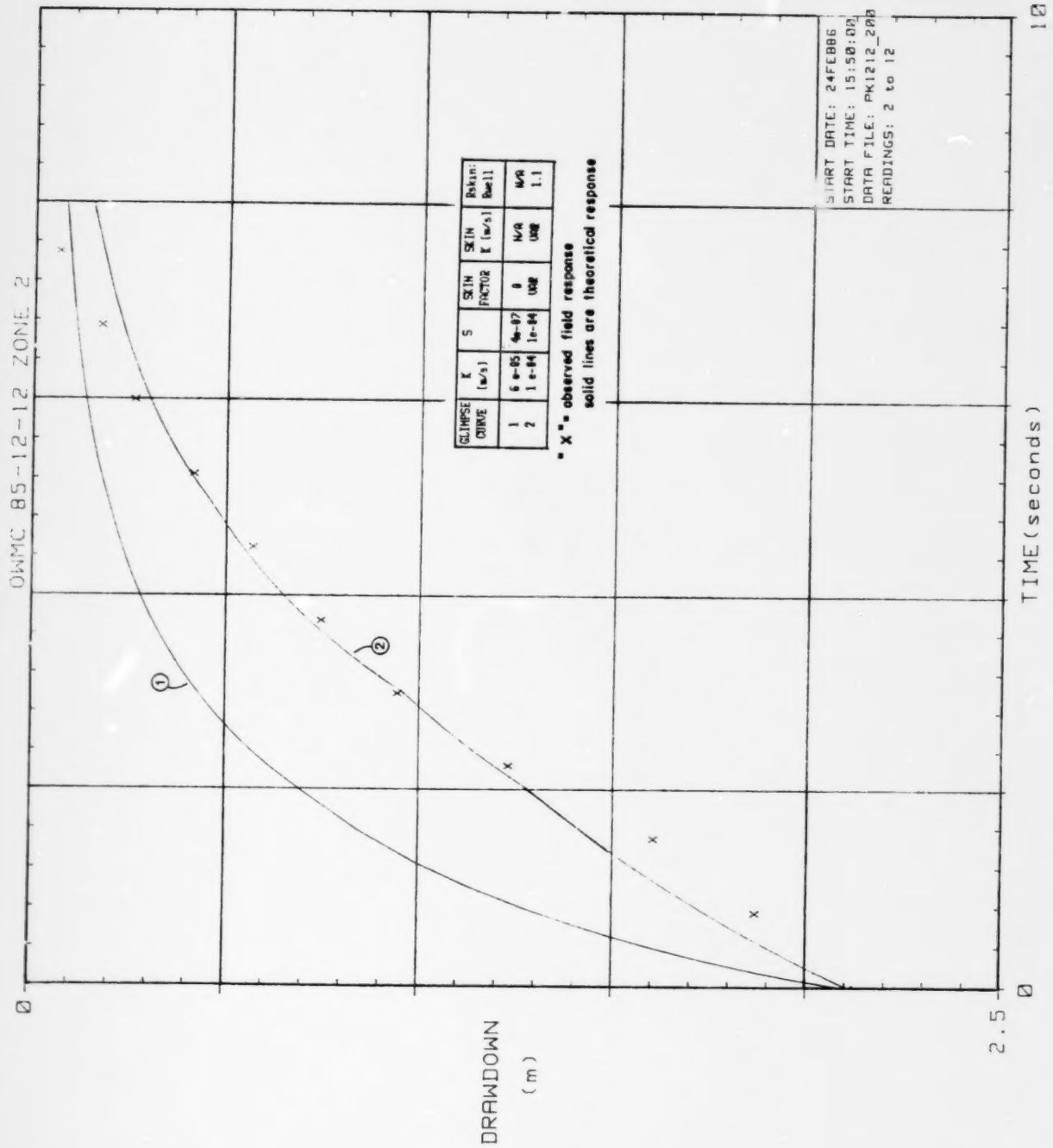
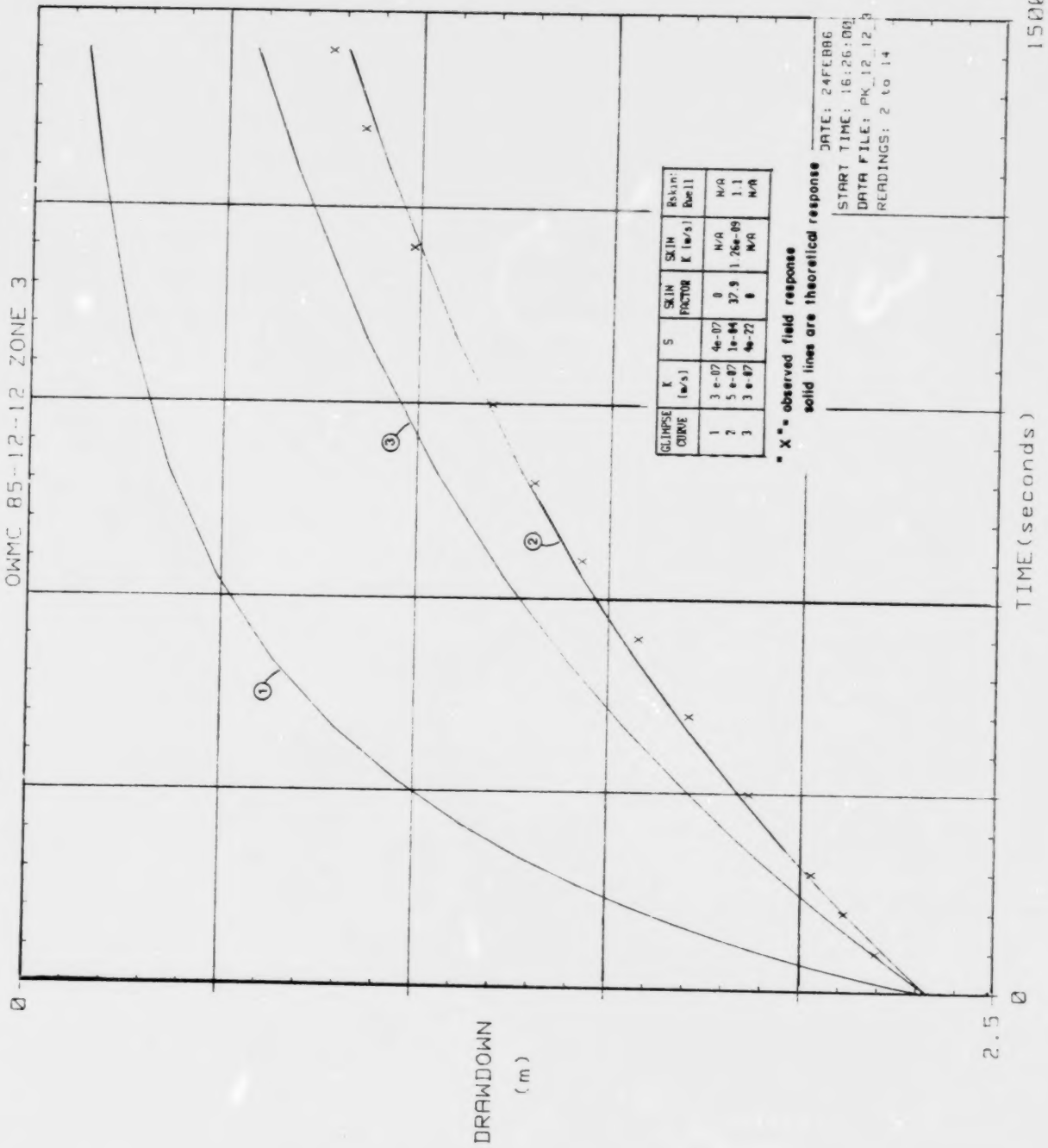


Figure G3-6
Glimpse Results For 85-12-12 Interval 3



G3.2 RESULTS

Table G3-1 summarizes the results of both the type curve and GLIMPSE model analyses performed on the packer test data. Also presented are static head measurements where these were available from the testing. The type curve results are taken from the Waterra Hydrogeology Inc. report (Section G3-4).

The values of $>6E-5$ m/s and $<3E-11$ m/s reported as hydraulic conductivities for the type-curve analysis respectively represent the upper and lower limits of this testing and analysis technique. Storativities were calculated from the type-curve analysis for selected intervals. It should be noted, however, that the results are relatively unreliable and have been included here only for completeness.

For borehole 85-1-12 interval 3 and borehole 85-12-12 interval 8, both constant head and slug test techniques were performed and analysed using the type-curve method. However, only the constant head result is reported here as Waterra Hydrogeology Inc. indicated it to be the more reliable result (Section G3.3).

Comparison of the results obtained from the two analysis techniques shows that the storativities obtained using the GLIMPSE simulation appear more reasonable. The values of hydraulic conductivity calculated by the type-curve method are generally less than about one-half order of magnitude lower than those obtained from the GLIMPSE simulation. This is within the normal range of accuracy in measuring hydraulic conductivity in the field and therefore results of the two analysis techniques are considered to be comparable. It should

TABLE G3-1: SUMMARY OF PACKER TEST ANALYSIS RESULTS

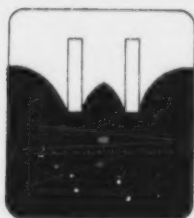
TEST INTERVAL		STATIC HEAD	TYPE-CURVE ANALYSIS		GLIMPSE ANALYSIS	
NO.	ELEVATION (m ASL)		HYDRAULIC COND. (m/s)	STORATIVITY	HYDRAULIC COND. (m/s)	STORATIVITY
<u>BOREHOLE 85-1-12</u>						
1	149.53-146.53	175.57	>6e-5	5.7e-22	2.0e-4	4.0e-7
2	146.53-143.53	176.84	>6e-5	5.7e-22		
3	143.53-140.53		1.7e-6			
4	140.53-137.53	176.95	1.7e-6	5.7e-4		
5	137.53-134.53	176.92	2.0e-5	5.7e-22	1.9e-5	4.0e-6
6	134.53-131.53		8.4e-9			
7	131.53-128.53		9.7e-9			
8	128.53-125.53		8.16e-9			
9	125.53-122.53	177.20	3.3e-7	5.7e-9	6.0e-7	1.0e-4
<u>BOREHOLE 85-12-12</u>						
1	145.19-142.19	176.45	>6e-5		2.0e-4	1.0e-4
2	142.19-139.19	176.47	>6e-5		1.0e-4	1.0e-4
3	139.19-136.19		2.9e-7		5.0e-7	1.0e-4
4	136.19-133.19	176.46	1.0e-5			
5	133.19-130.19	176.64	>6e-5			
6	130.19-127.19	176.50	>6e-5			
7	127.19-124.19	176.60	1.9e-5			
8	124.19-121.19		9.0e-9			
9	121.19-118.19		7.5e-11			
10	118.19-115.19		>3e-11			
11	114.29-111.79	176.52	9.0e-6			

be recognized that values of hydraulic conductivity resulting from GLIMPSE simulation that are greater than $6E-5$ m/s may be subject to inaccuracies resulting from limitations on the testing apparatus in high permeability formations, namely the minimum area available for flow. Consequently, the calculated value may be somewhat lower than the true formation hydraulic conductivity.

G3.3 WATERRA HYDROGEOLOGY INC. REPORT

Included in this section are copies of the report submitted to GLL by Waterra Hydrogeology Inc. The report consists of three letters to GLL, the contents of which are briefly summarized below:

- 1) February 14, 1986
 - Hydraulic testing procedures
 - Data analysis techniques
 - Results of testing in borehole 85-1-12
 - Slug test data (appended)
- 2) March 3, 1986
 - Results of testing in borehole 85-12-12
 - Slug test data (appended)
- 3) June 3, 1986
 - Amendments to earlier letters with respect to upper limit of hydraulic conductivity measurement



WATERRA
HYDROGEOLOGY INC.

February 14, 1986

Mr. Glen Reynolds
GaRTNER Lee Associates Ltd.
Toronto Buttonville Airport
Markham, Ontario, L3P 3J9

Dear Glen:

Attached are the results of the hydraulic tests that were conducted in borehole 85-1-12 at the OWMC site earlier this week.

Using a 3 metre packer spacing, nine separate intervals of the bedrock formation were tested between a depth of 36 and 63 metres below the ground surface. Hydraulic conductivity values were determined using either the slug-test method or the constant-head test method depending on the permeability of the interval. A brief description of test procedures for these two methods is given below.

HYDRAULIC TESTING PROCEDURES

- (1) Lower (or raise) straddle-packer assembly to desired position in borehole.
- (2) Lower electronic pressure sensor inside 3/4 inch standpipe to a fixed position (20 metres below the ground surface) and install surface valve and pressure gauge assembly on the top end of the standpipe.
- (3) Record the open hole water level and the corresponding pressure sensor output.
- (4) Inflate both packers to hydraulically isolate the test interval.
- (5) Monitor the pressure sensor output on the data logger and chart recorder. In permeable intervals, the pressure will quickly equilibrate to the static formation pressure. In low permeability intervals, the length of time required to reach equilibrium may exceed several hours or several days. For permeable intervals record equilibrated test interval pressure and conduct a slug-test to determine the hydraulic conductivity value. For the low permeability intervals, an accurate static level cannot be obtained. Conduct a constant-head test to determine the hydraulic conductivity value.

SLUG-TEST METHOD

- (6) Open valve on top of standpipe. This will instantly release the gas pressure and drop the test interval pressure by 70 Kpa (7 m head)
- (7) Monitor the pressure sensor output until the water level in the standpipe has fully recovered to the original static level

- (8) Deflate packers, remove pressure sensor and move packer assembly to next test interval.

CONSTANT-HEAD METHOD

- (6) Open valve on top of standpipe to release gas pressure. Fill the standpipe with water.
- (7) Using a graduated cylinder, add water to the standpipe to maintain the water level flush with the top end of the pipe. Calculate and record the flow-rate required to maintain this level.

DATA ANALYSIS

The slug test data was analysed using an analytical type-curve matching technique (Cooper et al, 1967). The hydraulic conductivity K is calculated using the formula

$$K = \frac{B r_c^2}{t b}$$

where B = match curve parameter
 t = time match curve parameter
 b = length of test interval
 r_c = effective radius of standpipe (0.0095 m)

The storage coefficient S can be calculated using the formula

$$S = \alpha r_c^2 / r_s^2$$

where α = matched type curve
 r_s = borehole radius

For the constant-head tests, the hydraulic conductivity value K is calculated using the steady-state formula

$$K = \frac{Q \ln(r_i / r_w)}{2 \pi \Delta H L}$$

where Q = steady-state flowrate
 r_i = radius of influence (5.0 m used for these tests)
 r_w = radius of borehole
 ΔH = Hydraulic head during injection of water (above static hydraulic head level)
 L = length of test interval

A summary of test results is presented in Table 1. The slug-test data for tests No. 1,2,3,4,5, and 9 are plotted on semi-log graph paper (Figure 1) and are also tabulated in Appendix A.

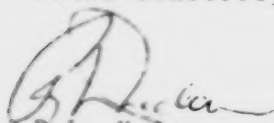
Static hydraulic head values were obtained for intervals 1,2,4,5, and 9. These head values indicate that there is an upward hydraulic gradient component in the rock mass.

For the 9 intervals tested, hydraulic conductivity values ranged from a low of 8.1×10^{-9} m/s (test No. 8) to a high of 1.0×10^{-4} m/s (test No. 1 and 2). I believe these values represent the lower and upper limits of the testing system. Therefore, it is quite likely that the hydraulic conductivity of tests 1 and 2 exceeds 1.0×10^{-4} m/s. Similarly, for tests 6,7, and 8, the hydraulic conductivity could be lower than 8×10^{-9} m/s. Modifications to the testing system would be required to expand the range of hydraulic conductivity measurement.

For test No. 3 (42.0 - 45.0 mbgs) a slug test and a constant-head test were performed. The hydraulic conductivity determined from the slug test was 100 times lower than that of the constant-head test. From the shape of the slug test curve (Figure 1) it is apparent that this interval has an unusually high storage coefficient (5.7×10^{-1}). This suggests the presence of a gas phase in the formation. If this is the case, the higher hydraulic conductivity obtained using the constant head method may be explained by the fact that, under higher testing pressure (approximately 170 kPa), the gas phase would compress and therefore, the hydraulic conductivity would be greater. For this reason, I believe that the constant-head test results are more reliable.

I trust that the information presented here satisfies your requirements. Please call me if you need any clarification or additional information.

Yours sincerely,


R.L. Nadon
Hydrogeologist

WATERRA HYDROGEOLOGY INC.

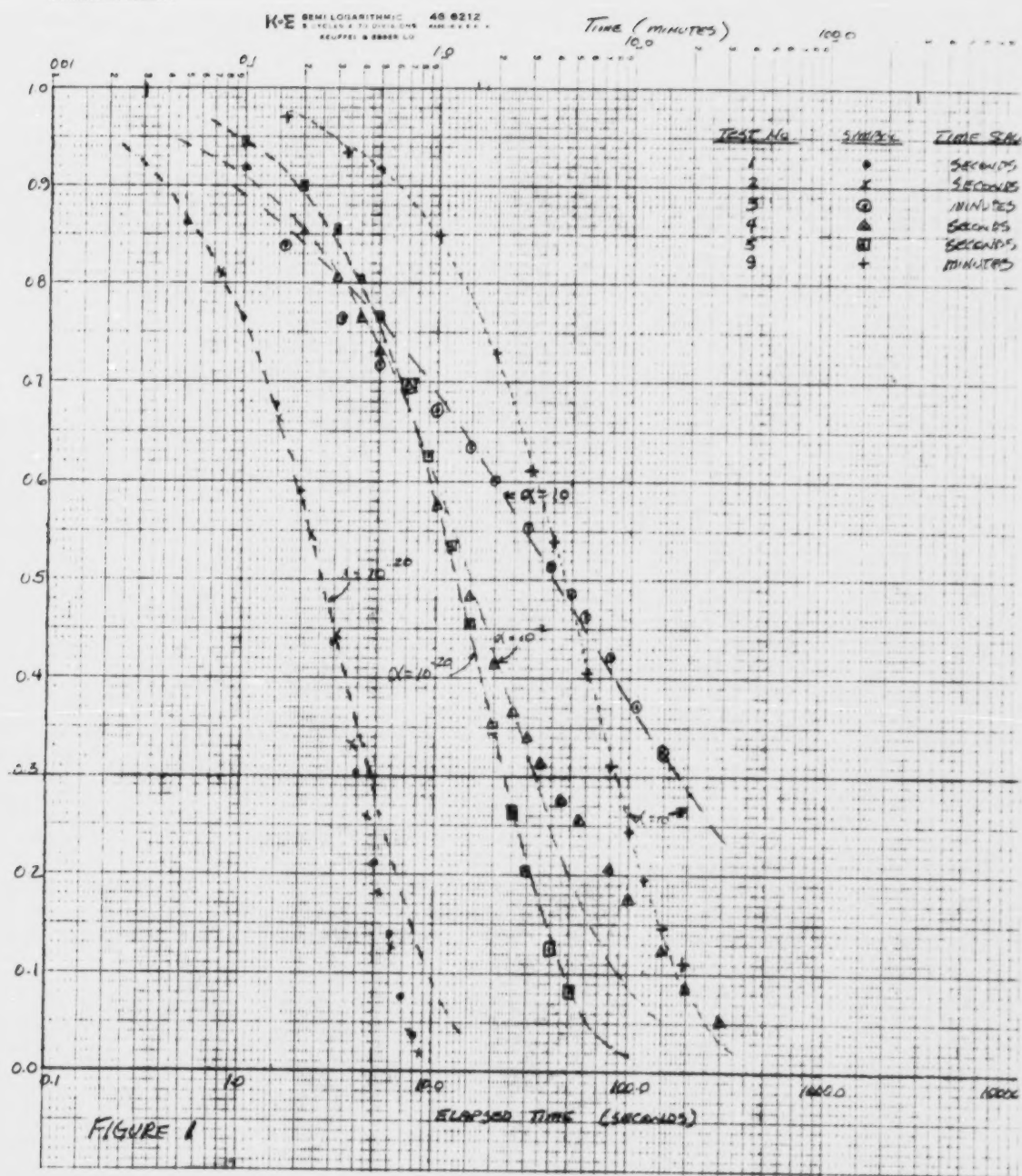
REFERENCE

- Hilton H. Cooper, Bredehoeft, J.D., Papadapulos, I.S.
Response of a Finite-Diameter Well to an Instantaneous
Charge of Water. Water Resources Research, Vol.3,
No. 1, 1967.

TABLE 1
HYDRAULIC TEST RESULTS

BOREHOLE: 85-1-12
DATE TESTED: FEB. 10, 11, 12, 1986

TEST NO.	TEST INTERVAL BELOW 6.5 (m)	STATIC HEAD BELOW 6.5 (m)	SLUG TEST MATCH POINT			CONSTANT HEAD TEST		HYD. CONDUCTIVITY (m/d)	STORAGE COEFFICIENT
			α	β	$x (d)$	$Q (m^3/d)$	$\Delta H (m)$		
1	36.0 - 39.0	9.96	10^{-20}	1	0.3	—	—	1.0×10^{-4}	5.7×10^{-22}
2	39.0 - 42.0	8.69	10^{-20}	1	0.3	—	—	1.0×10^{-4}	5.7×10^{-22}
3	42.0 - 45.0	—	10^{-1}	1	16800.0	—	—	1.8×10^{-9} 1.7×10^{-7}	5.7×10^{-1}
4	45.0 - 48.0	8.58	10^{-2}	1	17.5	—	—	1.7×10^{-6}	5.7×10^{-4}
5	48.0 - 51.0	8.61	10^{-20}	1	1.5	—	—	2.0×10^{-5}	5.7×10^{-22}
6	51.0 - 54.0	—	—	—	—	0.33	10.13	8.4×10^{-9}	—
7	54.0 - 57.0	—	—	—	—	0.38	10.13	9.7×10^{-9}	—
8	57.0 - 60.0	—	—	—	—	0.32	10.13	8.1×10^{-9}	—
9	60.0 - 63.0	8.33	10^{-7}	1	90.0	—	—	3.3×10^{-7}	5.7×10^{-9}



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APPENDIX A
SLUG TEST DATA

BOREHOLE No.: 85-1-12 TEST No: 1 TEST INTERVAL: 36.-39 m
TEST ZONE VOL.: — PISTON VOL.: — Brown GR surf.
DATE TESTED: 86-02-12 REFERENCE POINT: GROUND SURFACE

TIME		PRESSURE	ΔP_2	$P_2/\Delta P_2$	TEMP.
hr:min:sec	elap. (min)	P_2 mv	mv		mv
12:20:00	-3.0	744.1	—	—	—
12:21:00	-2.0	744.3	—	—	—
12:22:00	-1.0	744.8	—	—	—
12:22:30	-0.5	745.0	—	—	—
12:22:50	-0.166	745.1	—	—	—
12:23:00	0	480.1	265	1.0	
	(SECONDS)				
	0.5	516.4	228.7	0.862	
	1.0	542.6	202.5	0.764	
	1.5	565.1	180.0	0.679	
	2.0	588.6	156.5	0.590	
	3.0	629.1	116.0	0.438	
	4.0	664.6	80.5	0.304	
	5.0	689.1	56.0	0.211	
	6.0	708.1	37.0	0.140	
	7.0	724.6	20.5	0.087	
12:23:08	8.0	735.1	10.0	0.038	

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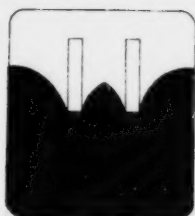
BOREHOLE No.: 85-1-12 TEST No: 2 TEST INTERVAL: 39 - 42 m

TEST ZONE VOL.: PISTON VOL.: *Below GR. 5.88*

DATE TESTED: 86-02-10 REFERENCE POINT: GROUND SURFACE

[illegible]

[illegible]



WATERRA
HYDROGEOLOGY INC.

March 3, 1986

Mr. Glen Reynolds
Gartner Lee Associates Ltd.
Toronto Buttonville Airport
Markham, Ontario, L3P 3J9

Dear Glen:

Attached are the results of the hydraulic tests that were conducted in borehole 85-12-12 at the OWMC site on February 24 & 25, 1986. The procedures used for testing this borehole were the same as those used for borehole 85-1-12 which are described in my letter of Feb. 14, 1986.

Eleven tests were performed in borehole 85-12-12 at 3-metre intervals between a depth of 39 and 72.4 metres below the ground surface. Where possible, static hydraulic heads were determined and hydraulic conductivity measured by either the slug-test or constant-head test methods. The methods used to analyse the data are described in my letter of Feb. 14, 1986.

The test results are summarised in Table 1. The data for the nine slug tests performed in BH 85-12-12 are plotted on a semi-log graph (Figure 1) and are also listed in separate tables in Appendix A.

For four test intervals (No. 1, 2, 4, and 5) hydraulic conductivity values equalled or exceeded the upper limit of the test system (approximately 1×10^{-5} m/s). You will note that for tests No. 9 and 10, hydraulic conductivity values lower than 10^{-10} m/s were measured. These low values indicate that the lower limit of the testing system is approximately 3×10^{-11} m/s. Therefore, for tests No. 6, 7, and 8 performed in borehole 85-1-12, the hydraulic conductivities listed in Table 1 (letter of Feb. 14, 1986) are more likely representative of the formation permeability rather than the lower limit of the testing system (due to rod leakage) as was originally thought to be the case.

I trust that the information presented here satisfies your requirements. Please contact me if you have any questions.

R.L. Nadon
Hydrogeologist

TABLE 1

HYDRAULIC TEST RESULTS BOREHOLE 85-12-12

TEST NO.	INTERVAL M.B.G.S.	STATIC HEAD M.B.G.S.	SILICO TEST PARAMETERS			CONSTANT HEAD TEST		HYDRAULIC CONDUCTIVITY (m/d.)
			α	β	$t(d)$	$Q(m/d.)$	$dh(m)$	
1	390-420	774	—	—	—	—	—	$> 1 \times 10^{-5}$
2	420-450	772	—	—	—	—	—	$> 1 \times 10^{-5}$
3	450-480	—	10^{-20}	1	103.2	—	—	2.9×10^{-7}
4	480-510	773	10^{-20}	1	3.0	—	—	1.0×10^{-5}
5	510-540	755	—	—	—	—	—	$> 1 \times 10^{-5}$
6	540-570	769	—	—	—	—	—	$> 1 \times 10^{-5}$
7	570-600	759	10^{-20}	1	16	—	—	1.9×10^{-5}
8	600-630	—	10^{-5}	1	768.0	—	—	3.9×10^{-8}
			—	—	—	0.317	8.15	9.0×10^{-9}
9	630-660	—	—	—	—	0.0027	8.97	7.5×10^{-11}
10	660-690	—	—	—	—	< 0.001	8.86	$< 2.9 \times 10^{-11}$
11	699-724	767	10^{-20}	1	4.0	—	—	9.0×10^{-6}

* M.B.G.S. = METERS BELOW GROUND SURFACE

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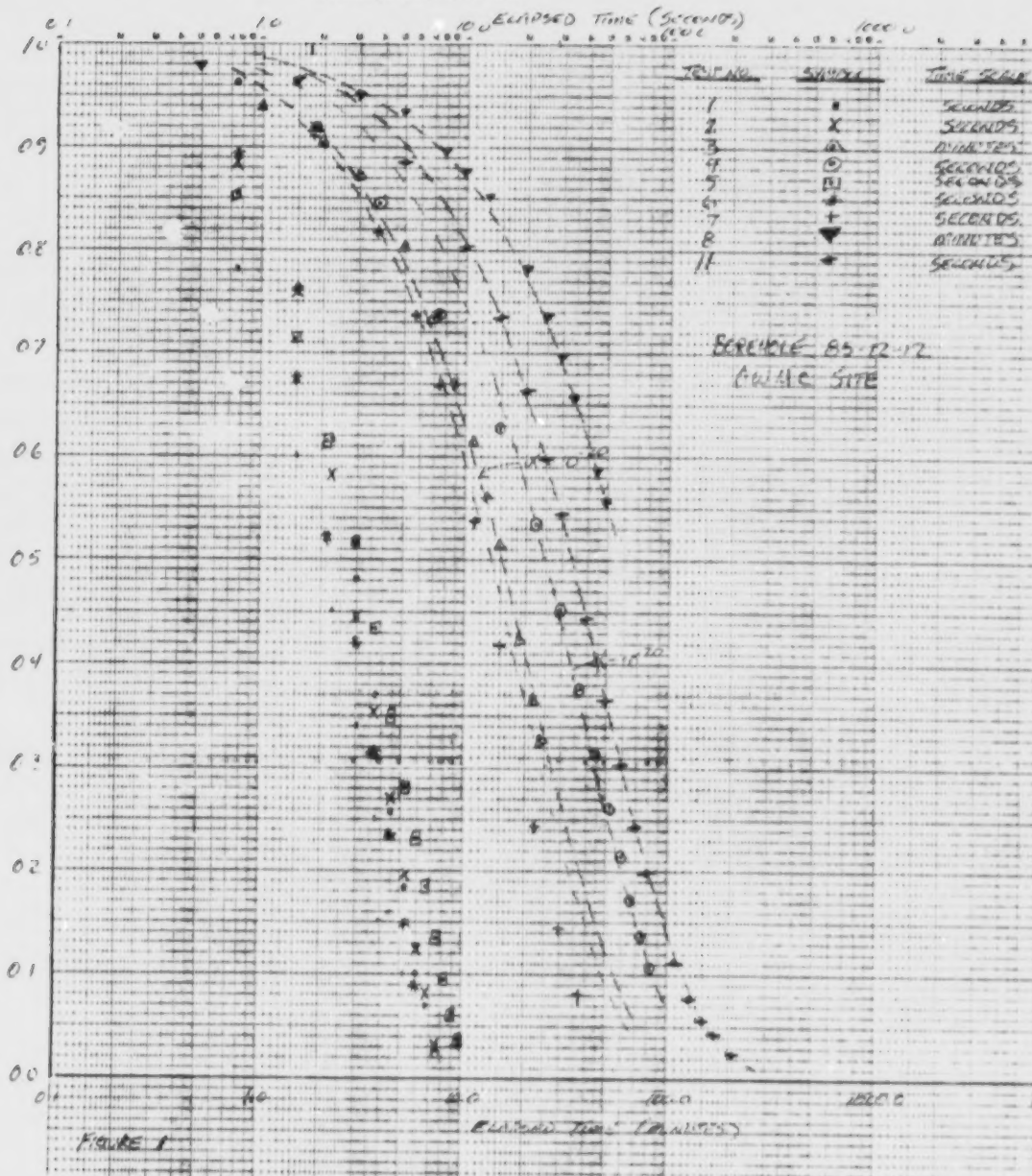


FIGURE 1

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APPENDIX A
SLUG TEST DATA

BOREHOLE No.: 85-12-12 TEST No: 1 TEST INTERVAL: 39-42
TEST ZONE VOL.: — PISTON VOL.: — MBS
DATE TESTED: 86 02-24 REFERENCE POINT: LIBOUND SURF

[illegible]

BOREHOLE No.: 85-12-12 TEST No: 2 TEST INTERVAL: 42-45

TEST ZONE VOL.: PISTON VOL.: MB4.5

DATE TESTED: 86 02-24 REFERENCE POINT: GROUND SURFACE

[illegible]

BOREHOLE No.: 85-12-12 TEST No: 3 TEST INTERVAL: 45-48
TEST ZONE VOL.: - PISTON VOL.: - MBGS
DATE TESTED: 86-01-24 REFERENCE POINT: GROUND SURFACE

[illegible]

BOREHOLE No.: 85-12-12 TEST No: 4 TEST INTERVAL: 48-51
TEST ZONE VOL.: — PISTON VOL.: — AM BGS
DATE TESTED: 86-02-24 REFERENCE POINT: GROUND SURFACE

[illegible]

BOREHOLE No.: 85-12-12 TEST No: 5 TEST INTERVAL: 51-54

TEST ZONE VOL.: — PISTON VOL.: — mbgs

DATE TESTED: 86-02-24 REFERENCE POINT: GROUND SURFACE

[illegible]

BOREHOLE No.: 85-12-12 TEST No.: 7 TEST INTERVAL: 57-60 m
 TEST ZONE VOL.: — PISTON VOL.: — mB65
 DATE TESTED: 86-02-25 REFERENCE POINT: GROUND SURFACE

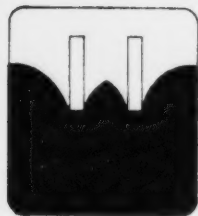
TIME		PRESSURE	ΔP_2	$P_2/\Delta P_2$	TEMP.	
hr:min:sec	elap. (min)	P_2 mv	mv		mv	
18:22:00	-10	855.2	—			
18:22:50	-0166	855.1	—			
18:23:00	0	695.1	160.0	1.0		
	(SECONDS)					
	1.875	708.1	147.0	0.919		
	3.75	724.1	131.0	0.819		
	5.625	737.1	118.0	0.737		
	7.5	748.1	107.0	0.669		
	11.25	769.1	86.0	0.537		
	15.0	788.1	61.0	0.419		
	22.5	816.1	39.0	0.214		
	30.0	832.1	23.0	0.144		
	37.5	842.1	13.0	0.081		

BOREHOLE No.: 85-12-12 TEST No.: 8 TEST INTERVAL: 60-63
 TEST ZONE VOL.: - PISTON VOL.: - m/BGS
 DATE TESTED: 86-02-25 REFERENCE POINT: GROUND SURFACE

TIME		PRESSURE P_2 mv	ΔP_2 mv	$P_2/\Delta P_2$	TEMP. mv	
hr:min:sec	elap. (min)					
9:10:00	-5.0	845.1	-			
9:12:00	-3.0	841.2	-			
9:14:00	-1.0	837.6	-			
9:14:50	-0.166	836.3	-			
9:15:00	0	799.7	36.6	1.0		
	0.5	800.4	35.9	0.980		
	1.5	801.0	35.3	0.964		
	3.0	801.5	34.8	0.950		
	5.0	802.1	34.2	0.934		
	8.0	803.5	32.8	0.896		
	10.0	804.2	32.1	0.877		
	13.0	805.1	31.2	0.852		
	20.0	807.7	28.6	0.781		
	25.0	809.3	27.0	0.737		
	30.0	810.8	25.5	0.696		
	35.0	812.2	24.1	0.658		
	45.0	815.1	21.2	0.589		
	50.0	816.3	20.0	0.556		

BOREHOLE No.: 85-12-12 TEST No: 11 TEST INTERVAL: 69.9-72.4TEST ZONE VOL.: PISTON VOL.: MBG5DATE TESTED: 86-02-25 REFERENCE POINT: GROUND SURFACE

TIME		PRESSURE	ΔP_2	$P_2/\Delta P_2$	TEMP.	
hr:min:sec	elap. (min)	P_2 mv	mv		mv	
17:29:00	-2.0	871.3	—	—		
17:30:00	-1.0	866.0	—	—		
17:30:50	-0.166	865.5	—	—		
17:31:00	0	784.6	80.9	1.0		
	~~BT~~ SECONDS					
	5	793.8	71.7	0.886		
	10	800.5	65	0.803		
	15	806.0	59.5	0.735		
	20	811.8	53.7	0.664		
	25	817	48.5	0.599		
	30	821.5	44.0	0.544		
	40	829.6	35.9	0.444		
	50	835.9	29.6	0.366		
	60	841.1	24.4	0.302		
	70	845.8	19.7	0.244		
	80	849.3	16.2	0.200		
	110	856.4	9.1	0.112		
	130	859.2	6.3	0.078		
	150	860.9	4.6	0.057		
	170	862.0	3.5	0.043		
	200	863.5	2.0	0.025		



WATERRA
HYDROGEOLOGY INC.



June 16, 1986

Mr. S. Hollinghead
GARTNER LEE ASSOCIATES
Toronto Buttonville Airport
Markham, Ontario
L3P 3J9

Dear Mr. Hollingshead:

As you requested, I have reviewed the borehole hydraulic test data collected at the West Lincoln Site to determine the upper limit of the packer probe system for measuring hydraulic conductivity.

Based on this review, I recommend that hydraulic conductivity values for tests No. 1 and 2 (borehole 85-1-12, letter of Feb. 14, 1986) and tests 1, 2, 5, and 6 (borehole 85-12-12, letter of March 3, 1986) be listed as greater than 5×10^{-5} m/s. The permeability of the above six test zones is greater than this upper limit and too high for the testing system to accurately quantify.

Please call me if you have any other questions.

Yours sincerely,

R.L. Nadon

WATERRA HYDROGEOLOGY INC.

G4 PUMP TESTING

A pump test was performed in borehole 85-1-22 to determine the hydraulic conductivity of the shallow bedrock aquifer, identified as Zone A. This section describes the analysis and results of the pump test.

G4.1 DATA COLLECTION AND ANALYSIS

The techniques used to perform and collect data from the pump test at the Preferred Site are described in Appendix A3.4 of this report.

The responses measured in the pumping well and at two observation wells were analysed using the Theis method for pumping test data analysis. The method of solution is presented in Kruseman and de Ridder (1970).

G4.2 RESULTS

Data obtained from the pumping test are presented in Tables G4-1 to G4-3. Both pumping and recovery data are included. Selected data from these tables were analysed using the technique identified in Kruseman and de Ridder (1970). The type curves, associated match points, and calculations for each of these analyses are shown in Figures G4-1 to G4-3. The symbol "x" on each plot represents the observed response to pumping, while the solid line is the match plot used for analysis. The results of the pump test analyses are summarized below.

MONITOR NUMBER	DISTANCE FROM PUMPED WELL (m)	TRANSMISSIVITY T (m /s)	STORATIVITY S
85-1-22	-	2.2E-3	-
85-1-12	3.3	1.8E-3	5.8E-4
85-1-1	6.1	2.0E-3	6.7E-5

G-54

JOB NAME : QWMC 85-1-22 PUMPED WELL

READING #	READING DESCRIPTION	DATE (DDMMYY)	TIME (HH:MM:SS)	DEPTH TO WATER (m)
1	START PUMP (Q=7E-4 m ³ /s) @ STATIC	22APR86	16:33:00	9.94
2	PUMPING	22APR86	16:33:30	10.09
3	PUMPING	22APR86	16:33:40	10.09
4	PUMPING	22APR86	16:33:50	10.12
5	PUMPING	22APR86	16:34:00	10.10
6	PUMPING	22APR86	16:34:30	10.11
7	PUMPING	22APR86	16:35:00	10.12
8	PUMPING	22APR86	16:35:30	10.13
9	PUMPING	22APR86	16:36:30	10.14
10	PUMPING	22APR86	16:38:00	10.15
11	PUMPING	22APR86	16:40:00	10.16
12	PUMPING	22APR86	16:43:00	10.17
13	PUMPING	22APR86	16:48:00	10.18
14	PUMPING	22APR86	16:58:00	10.19
15	PUMPING	22APR86	17:18:00	10.20
16	PUMPING	22APR86	18:33:00	10.23
17	PUMPING	22APR86	19:33:00	10.25
18	PUMPING	23APR86	08:00:00	10.25
19	PUMPING	23APR86	09:00:00	10.28
20	PUMPING	23APR86	10:15:00	10.28
21	END OF PUMPING	23APR86	10:45:00	10.28

Table G4 - I

Pumping Test Data For Pumping Well 85-1-22

G-55

JOB NAME : OWMC PUMPTST LONG 85-1-12

READING #	READING DESCRIPTION	DATE (DDMMYY)	TIME (HH:MM:SS)	DEPTH TO WATER (m)
1	START PUMP (Q=7E-4 m ³ /s) @ STATIC	22APR86	16:33:00	10.00
2	PUMPING	22APR86	16:33:10	10.12
3	PUMPING	22APR86	16:33:20	10.09
4	PUMPING	22APR86	16:33:30	10.11
5	PUMPING	22APR86	16:33:50	10.11
6	PUMPING	22APR86	16:34:00	10.11
7	PUMPING	22APR86	16:34:30	10.13
8	PUMPING	22APR86	16:35:00	10.14
9	PUMPING	22APR86	16:35:30	10.14
10	PUMPING	22APR86	16:36:00	10.15
11	PUMPING	22APR86	16:37:00	10.15
12	PUMPING	22APR86	16:38:00	10.17
13	PUMPING	22APR86	16:40:00	10.18
14	PUMPING	22APR86	16:53:00	10.21
15	PUMPING	22APR86	16:58:00	10.21
16	PUMPING	22APR86	17:03:00	10.21
17	PUMPING	22APR86	17:18:00	10.22
18	PUMPING	22APR86	17:33:00	10.23
19	PUMPING	22APR86	18:33:00	10.26
20	PUMPING	22APR86	19:33:00	10.27
21	PUMPING	22APR86	20:33:00	10.28
22	PUMPING	22APR86	22:33:00	10.28
23	PUMPING	23APR86	08:00:00	10.26
24	PUMPING	23APR86	09:00:00	10.30
25	END PUMPING	23APR86	10:45:00	10.30
26	RECOVERY	23APR86	10:45:10	10.20
27	RECOVERY	23APR86	10:45:20	10.25
28	RECOVERY	23APR86	10:45:30	10.20
29	RECOVERY	23APR86	10:45:40	10.20
30	RECOVERY	23APR86	10:45:50	10.18
31	RECOVERY	23APR86	10:46:30	10.16
32	RECOVERY	23APR86	10:47:00	10.15
33	RECOVERY	23APR86	10:47:30	10.14
34	RECOVERY	23APR86	10:48:00	10.13
35	RECOVERY	23APR86	10:49:00	10.12
36	RECOVERY	23APR86	10:52:00	10.11
37	RECOVERY	23APR86	10:55:00	10.10
38	RECOVERY	23APR86	11:05:00	10.09
39	RECOVERY	23APR86	11:15:00	10.09
40	RECOVERY	23APR86	11:45:00	10.07
41	RECOVERY	23APR86	12:15:00	10.04

Table G4-2

Pumping Test Data For Observation Well 85-1-12

JOB NAME : OWMC PUMPTST 85-1-1 LONG

READING #	READING DESCRIPTION	DATE (DDMMYY)	TIME (HH:MM:SS)	DEPTH TO WATER (m)
1	START PUMFING (Q=7E-4 m ³ /s)	22APR86	16:33:00	9.58
2	PUMPING	22APR86	16:33:10	9.71
3	PUMPING	22APR86	16:33:20	9.70
4	PUMPING	22APR86	16:33:40	9.70
5	PUMPING	22APR86	16:33:50	9.71
6	PUMPING	22APR86	16:34:00	9.72
7	PUMPING	22APR86	16:34:30	9.73
8	PUMPING	22APR86	16:35:00	9.73
9	PUMPING	22APR86	16:35:30	9.74
10	PUMPING	22APR86	16:36:00	9.75
11	PUMPING	22APR86	16:38:00	9.76
12	PUMPING	22APR86	16:40:00	9.78
13	PUMPING	22APR86	16:43:00	9.78
14	PUMPING	22APR86	16:48:00	9.79
15	PUMPING	22APR86	16:53:00	9.80
16	PUMPING	22APR86	17:18:00	9.81
17	PUMPING	22APR86	17:33:00	9.82
18	PUMPING	22APR86	17:33:00	9.82
19	PUMPING	22APR86	18:33:00	9.85
20	PUMPING	22APR86	19:33:00	9.87
21	PUMPING	22APR86	20:33:00	9.87
22	PUMPING	23APR86	08:00:00	9.86
23	PUMPING	23APR86	09:00:00	9.90
24	END PUMPING	23APR86	10:45:00	9.90
25	RECOVERY	23APR86	10:45:10	9.80
26	RECOVERY	23APR86	10:45:20	9.80
27	RECOVERY	23APR86	10:45:50	9.78
28	RECOVERY	23APR86	10:46:00	9.75
29	RECOVERY	23APR86	10:47:00	9.74
30	RECOVERY	23APR86	10:48:00	9.73
31	RECOVERY	23APR86	10:49:00	9.72
32	RECOVERY	23APR86	10:50:00	9.71
33	RECOVERY	23APR86	10:55:00	9.69
34	RECOVERY	23APR86	11:00:00	9.68
35	RECOVERY	23APR86	11:15:00	9.68
36	RECOVERY	23APR86	11:45:00	9.67
37	RECOVERY	23APR86	12:15:00	9.66
38	RECOVERY	23APR86	13:15:00	9.66
39	RECOVERY	23APR86	15:53:00	9.63

Table G4.3

Pumping Test Data For Observation Well 85-1-1

Figure G4-1
Pumping Test Analysis For 85-1-22

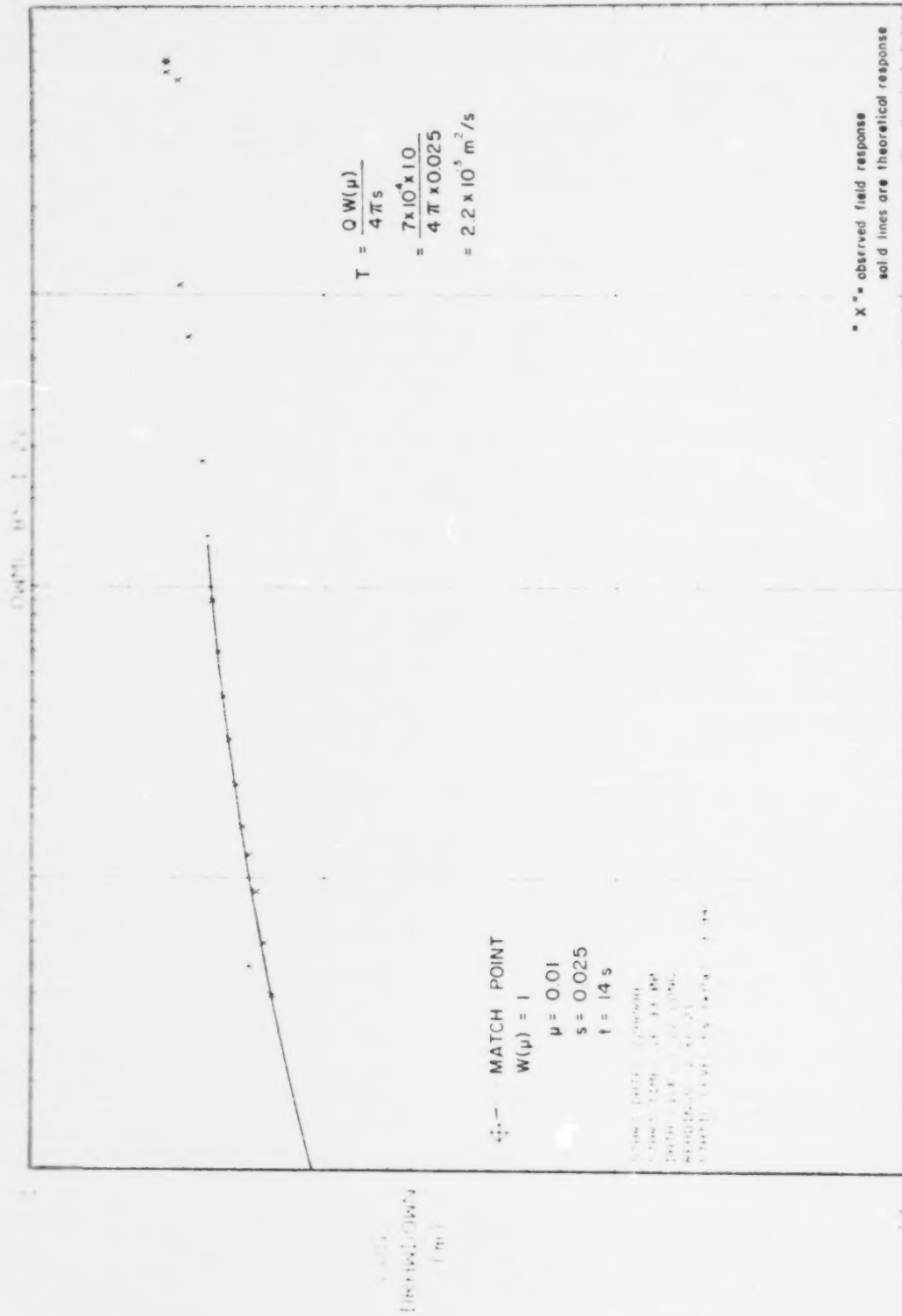


Figure G4-2
Pumping Test Analysis For 85-1-12

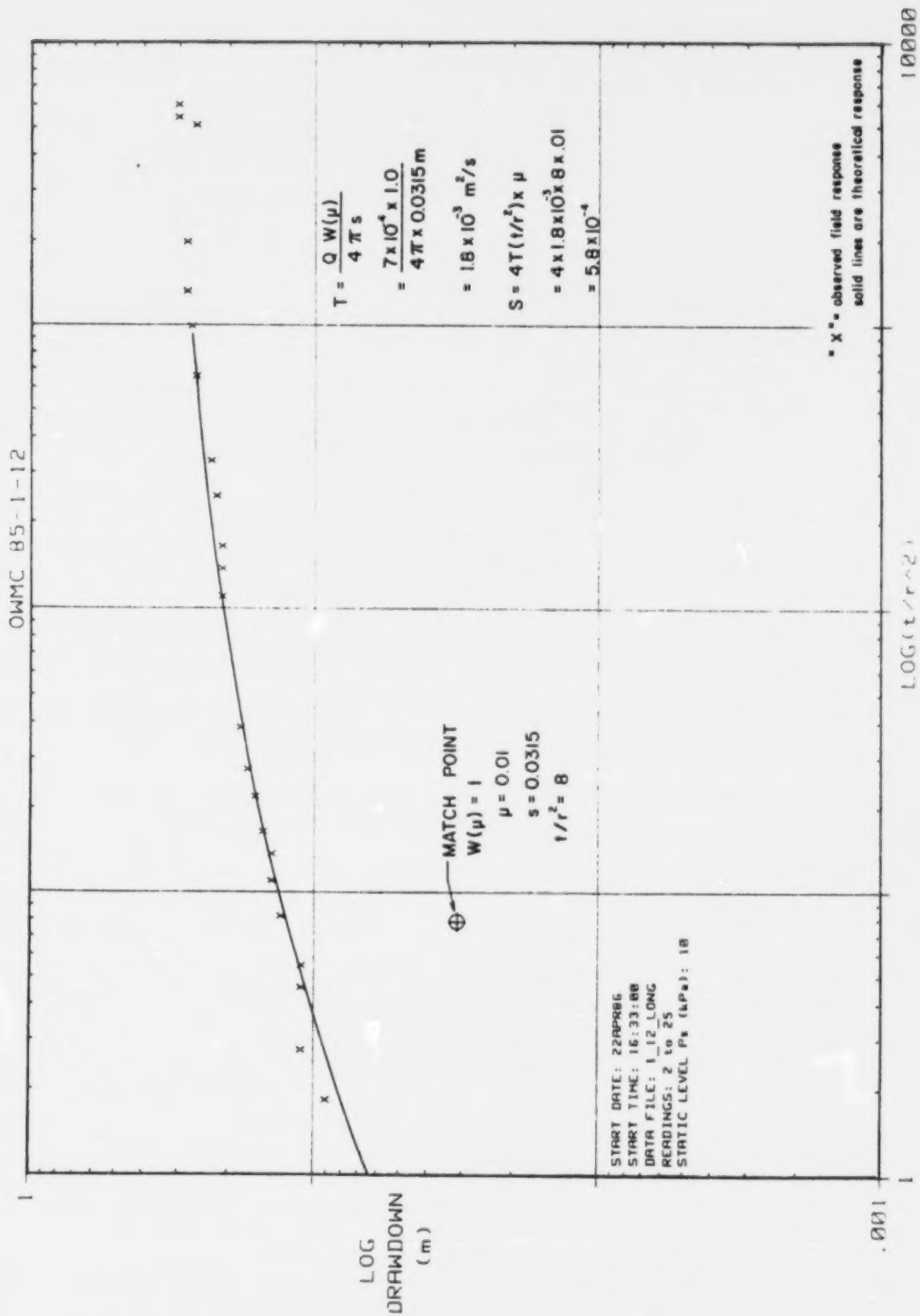
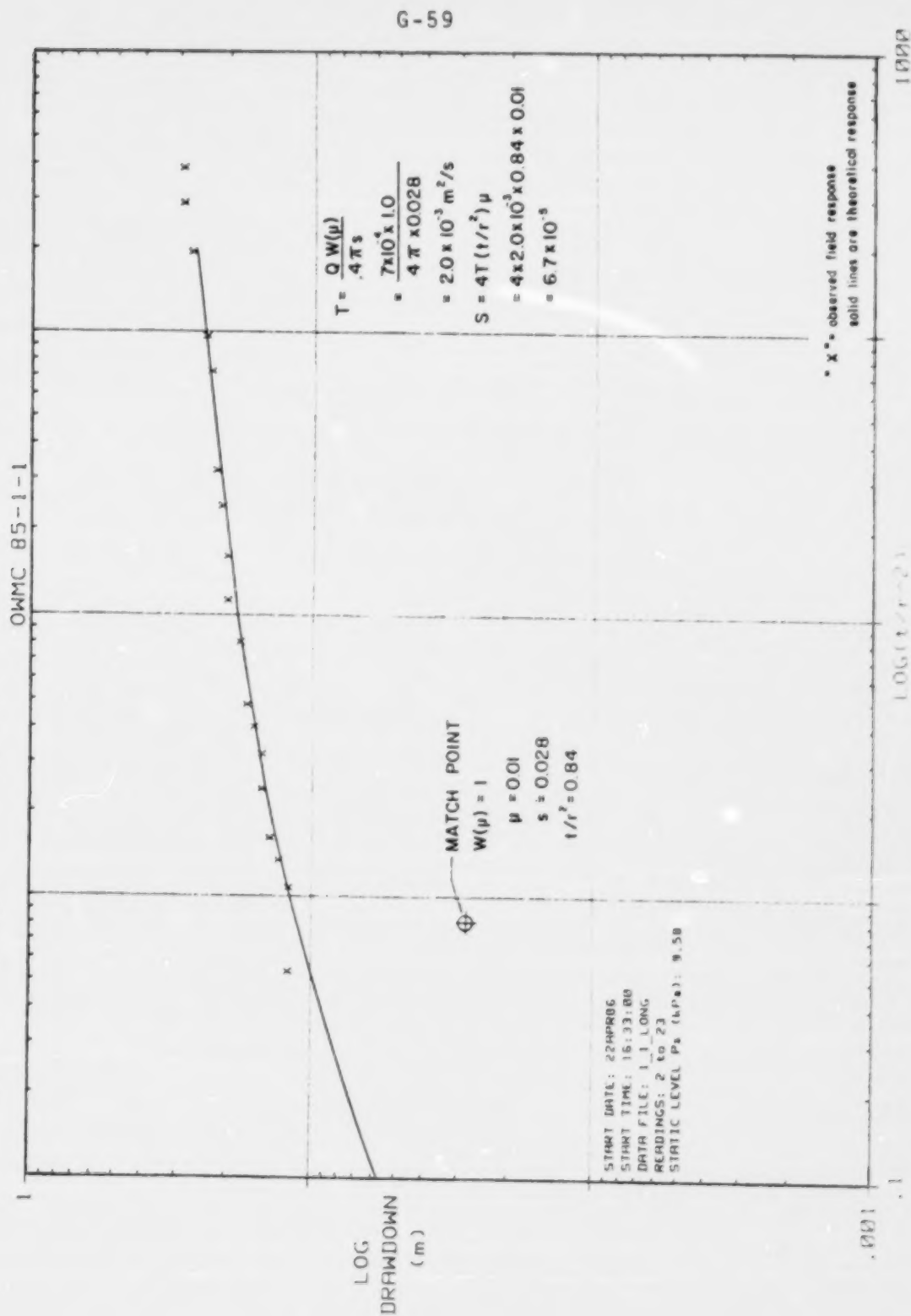


Figure G4-3
Pumping Test Analysis For 85-1-1



The field data proved to be well suited to the Theis curve analysis method for transient flow in a confined aquifer as the match curves are quite close to the observed data. The pumping response suggests that leakage through the aquitard is negligible relative to aquifer flow. Hydraulic conductivity for the bedrock aquifer can be calculated by dividing the transmissivity obtained from the pumping test by the effective thickness of the aquifer tested. Because the bedrock fractures are predominantly horizontal, related to bedding (Section 2.0), and the test pumping rate was low, the effective thickness of the aquifer is considered to be the 2 m screen length rather than the 6 m thickness of Zone A. The resulting hydraulic conductivity is estimated to be $1\text{E-}3$ m/s.

G5 LABORATORY TESTING

Golder Associates (Eastern Canada) Limited performed hydraulic conductivity testing on Shelby tube samples provided by GLAL. The purpose and scope of the testing program were presented in Appendix A3.5 of this report.

G5.1 GOLDER ASSOCIATES REPORT

Included in this section is a copy of the report submitted by Golder Associates to Gartner Lee dated July 1986. The contents of the Golder Associates' report are briefly summarized below:

- letter of transmittal for report (July 28, 1986);
- letter of transmittal for corrected copies of Figures 41 and 43 (August 6, 1986), note that these are included in the attached copy;
- introductory letter explaining the contents of the report (July 25, 1986);
- summary of test results (Table 1);
- detailed description of laboratory testing procedure (Appendix A); and
- detailed test results for each sample (Figures 1 to 60).

Note that in Golder Associates' report, hydraulic conductivity is termed "coefficient of permeability" and is reported in units of cm/s rather than m/s. The appropriate conversion factor is $1 \text{ m/s} = 100 \text{ cm/s}$.



Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

TRANSMITTAL LETTER



To Gartner Lee Associates Limited
Toronto-Buttonville Airport
MARKHAM, Ontario
L3P 3J9

Date July 28, 1986

Project No. 861-1121

GLAL No. 85-GH-8

ATTENTION: Mr. Steve Hollingshead

Sent by

- ☐ Mail
☐ Air Freight
☐ Hand Carried

- ☐ Under Separate Cover
☒ Enclosed
x COURIER

Quantity	Item	Description
1	Factual Report (bound)	<u>CONFIDENTIAL</u> LABORATORY PERMEABILITY TESTING OF CLAY SOILS ONTARIO WASTE MANAGEMENT CORPORATION 4B PROGRAM
1	(unbound)	Photographs.
Remarks		

Per

F. A. Rydgren
F. A. Rydgren


Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

TRANSMITTAL LETTER

To Gartner Lee Associates Limited
 Toronto-Buttonville Airport
 MARKHAM, Ontario
 L3P 3J9

Date August 6, 1986

Project No. 861-1121

GLAL No. 85-GH-8

ATTENTION: Mr. Steve Hollingshead

Sent by

- ☐ Mail
☐ Air Freight
☐ Hand Carried

- ☐ Under Separate Cover
☒ Enclosed

Quantity	Item	Description
2 each	Figure 41 Figure 43	<u>CONFIDENTIAL</u> Triaxial Permeability Tests BH 85-12-8, Sample 1 Vertical BH 85-12-8, Sample 1 Horizontal
Remarks Corrected copies for report.		

Per

F. A. Rydgren
 F. A. Rydgren



Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

FACTUAL REPORT TO
GARTNER LEE ASSOCIATES LIMITED

CONFIDENTIAL

LABORATORY PERMEABILITY TESTING
OF CLAY SOILS

ONTARIO WASTE MANAGEMENT
CORPORATION

4B PROGRAM

Gartner Lee Associates Ref. 85-GH-8

DISTRIBUTION:

1 copy, bound - Gartner Lee Associates Limited
1 copy, unbound Markham, Ontario
2 copies, bound - Golder Associates
Mississauga, Ontario

July, 1986

861-1121



Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

July 25, 1986

Our ref: 861-1121

Gartner Lee Associates Limited
Toronto-Buttonville Airport
MARKHAM, Ontario
L3P 3J9

ATTENTION: Mr. Steve Hollingshead

RE: LABORATORY PERMEABILITY TESTING
OF CLAY SOILS
ONTARIO WASTE MANAGEMENT CORPORATION
4B PROGRAM
GLAL REF: 85-GH-8

Dear Sirs:

This letter reports the factual results of coefficient of permeability tests carried out on samples of clay soils delivered to our laboratory by Gartner Lee Associates Limited. We understand that the samples were obtained from various sites within the OWMC 4B program. The results of other laboratory testing from the same sites are given in our Report 851-1298 dated May 9, 1986.

LABORATORY TESTING

The coefficient of permeability tests were carried out in our geotechnical laboratory in Mississauga, Ontario, using the testing program as specified by Gartner Lee Associates Limited, letter dated April 29, 1986.

TEST SAMPLES

During the period from December 6, 1985 to March 14, 1986, our laboratory received samples for testing from Gartner Lee Associates. These samples were delivered in 2-7/8 in. Shelby tubes which were sealed with paraffin wax and stored horizontally in our concrete curing room until required for testing.

CONSTANT HEAD PERMEABILITY TESTING

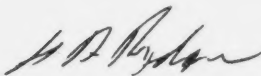
The constant head permeability tests were carried out on pre-selected site/borehole samples, with a vertical direction and horizontal direction test on each sample. The results of these tests are summarized on Table 1 and the computer data information is shown on Figures 1 to 60, inclusive. The figures are assembled by site location sequence 1, 3, 8, 10 and 12.

In addition to the enclosed figures there is an appendix covering the procedure which is used by Golder Associates in carrying out the constant head permeability tests.

Due to the length of the testing program, some preliminary results on Sites 1, 3 and 12 were forwarded to your office on our letter of June 13, 1986, accompanied by laboratory photographs.

We trust that this information is adequate for your purposes.
If there are any questions regarding this report, please
contact us.

Yours truly
GOLDER ASSOCIATES


F. A. Rydgren


Leo R. Lahti, P. Eng.



FAR/LRL/jm

Enc: Table 1
Figures 1 to 60
Appendix - Constant Head Permeability
Test Procedure

July, 1986

TABLE 1

861-1121
85-GH-8

SUMMARY OF COEFFICIENT OF PERMEABILITY TEST RESULTS

FIGURE NO.	SITE NO.	BOREHOLE NO.	SAMPLE NO.	DEPTH (m)	DIRECTION (degrees)	CONSOLIDATION PRESSURE (kPa)	COEFFICIENT OF PERMEABILITY (cm/s)
1, 2	85-1	2	11	10.10	90	99.9	1.44×10^{-8}
3, 4	85-1	2	11	9.82	0	99.9	2.07×10^{-8}
5, 6	85-1	2	17	15.72	90	159.8	5.15×10^{-9}
7, 8	85-1	2	17	15.68	0	159.8	6.17×10^{-9}
9, 10	85-1	2	26	25.32	90	259.8	1.12×10^{-8}
11, 12	85-1	2	26	25.22	0	259.8	1.25×10^{-8}
13, 14	85-1	8	2	4.17	90	48.2	1.68×10^{-8}
15, 16	85-1	8	2	3.97	0	48.2	1.58×10^{-8}
17, 18	85-3	2	15	18.72	90	190.9	1.79×10^{-8}
19, 20	85-3	2	15	18.42	0	190.2	1.65×10^{-8}
21, 22	85-3	2	20	26.35	90	270.1	1.86×10^{-8}
23, 24	85-3	2	20	26.30	0	270.1	1.90×10^{-8}
25, 26	85-8	8	2	4.09	90	44.8	7.54×10^{-9}
27, 28	85-8	8	2	3.99	0	44.8	1.77×10^{-8}
29, 30	85-8	8	6	22.43	90	230.1	1.96×10^{-8}
31, 32	85-8	8	6	22.33	0	230.1	2.19×10^{-8}
33, 34	85-10	2	16	16.22	90	159.8	8.97×10^{-7}
35, 36	85-10	2	16	16.13	0	159.8	1.17×10^{-6}
37, 38	85-10	2	24	25.27	90	259.8	2.67×10^{-8}
39, 40	85-10	2	24	25.02	0	259.8	2.69×10^{-8}
41, 42	85-12	8	1	11.13 3.67	90	44.8	3.63×10^{-8}
43, 44	85-12	8	1	11.03 3.44	0	44.8	1.54×10^{-8}
45, 46	85-12	8	3	11.13	90	110.2	4.61×10^{-8}
47, 48	85-12	8	3	10.96	0	110.2	2.26×10^{-8}
49, 50	85-12	8	5	21.72	90	230.1	1.68×10^{-8}
51, 52	85-12	8	5	21.69	0	230.1	3.23×10^{-8}
53, 54	85-12	22	2	15.33	90	159.8	2.67×10^{-8}
55, 56	85-12	22	2	15.28	0	159.8	3.75×10^{-8}
57, 58	85-12	22	4	28.60	90	319.7	1.22×10^{-8}
59, 60	85-12	22	4	28.45	0	319.7	2.63×10^{-8}

DIRECTION OF SAMPLE IN DEGREES IS FROM THE HORIZONTAL PLANE.

APPENDIX

CONSTANT HEAD PERMEABILITY TEST PROCEDURE

Ref.: The Triaxial Test, Bishop & Henkel

CONSTANT HEAD PERMEABILITY TEST PROCEDURE

The constant head permeability tests were carried out using the pore water pressure mercury/water triaxial apparatus.

The test samples were extruded from the 2-7/8 in. Shelby tubes and trimmed to test size at 0° or 90° to the horizontal plane. After placing on the cell pedestal, with 80 Kv bauxite filter stones on each end, the samples were encased with high vacuum grease, membrane sheath, high vacuum grease and a second membrane sheath. The triaxial cell was then assembled and filled with water.

Saturation by Back Pressure

The test samples were saturated by back pressures at incremental stages of 70 kPa until a pore pressure B value of 0.96 was obtained.

For a saturation incremental stage, a cell pressure of 70 kPa and a back pressure of 62 kPa is introduced to the sample and allowed to absorb air for about 8 hours prior to increasing to the next increment until saturation has been completed.

Isotropic Consolidation

Upon achieving saturation, the cell pressure was increased above the saturation back pressure to a value that would equal the required effective consolidation pressure.

The sample was then allowed to consolidate for a minimum period of 24 hours, at which time the consolidated sample size was calculated. Using the consolidated length value,

a hydraulic gradient of approximately 20 was calculated and the required head pressure was applied to one end of the sample while the saturation back pressure was applied to the opposite end. In order to maintain the original consolidation pressure, the cell pressure was adjusted so that the differences between the head pressure and cell pressure were equal to the required isotropic consolidation.

Permeability Test

Upon completion of the saturation, consolidation and head pressure adjustment stages, the permeability stage proceeds with periodic readings of the inflow and outflow volume change instruments until a stable flow path has been achieved. The coefficient of permeability is then calculated from the flow graphs.

TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 1

BOREHOLE NUMBER 85-1-2 PROJECT 861-1121
 SAMPLE NUMBER 11 Vertical Direction
 SAMPLE DEPTH 18.18 m (61AL PROJECT 885-6H-8)
 SAMPLE TYPE Layered silty clay and clay with fine gravel

ORIGINAL: LENGTH cm	6.910	CONSOLIDATED: AREA cm ²	19.27	WET WEIGHT gm	287.8
DIAMETER cm	4.980	LENGTH cm	6.87	DRY WEIGHT gm	243.5
AREA cm ²	19.481	PRESSURE kPa	99.9	VOLUME WATER cc	44.3
VOLUME cc	134.612	HYDRAULIC GRADIENT (p/1)	20.36		

WATER CONTENT initial %	18.20	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	18.60	VOLUME SOLIDS cc	87.590	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.96	VOLUME VOIDS cc	47.022	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	17.73	VOID RATIO	0.537	SILT FRACTION (.06mm) %	
lb/ft ³	112.87	SATURATION %	94.212		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
137.8	130.9	1331	1.0	0.99

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure	Top	Base
kPa	kPa	kPa	kPa			kPa	kPa
244.6	144.7	130.9	13.79	2711.276	99.9		113.7

DATE	CLOCK	ELAPSED TIME	ELAPSED TIME	Vc	aVc	Vc	aVc	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	min.	sec.	cc	cc	cc	cc	INFLOW	OUTFLOW
								cm/s	cm/s
86-05-02	08:55	0	0	54.00	0.0	36.00	0.0		
86-05-02	14:23	320	19600	53.70	0.30	35.90	0.10	3.86E-08	1.29E-08
86-05-02	16:28	453	27180	53.50	0.50	35.80	0.20	6.76E-08	3.38E-08
86-05-05	08:48	4313	258780	52.50	1.50	34.30	1.70	1.09E-08	1.64E-08
86-05-06	08:54	5759	345540	52.20	1.80	33.70	2.30	8.76E-09	1.75E-08

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
5759	OUTFLOW, k	3.15E-08	5431	OUTFLOW, k	1.17E-08 cm/s
	AVERAGE, k	2.01E-08		AVERAGE, k	1.71E-08 cm/s
		2.58E-08			1.44E-08 cm/s

NOTES

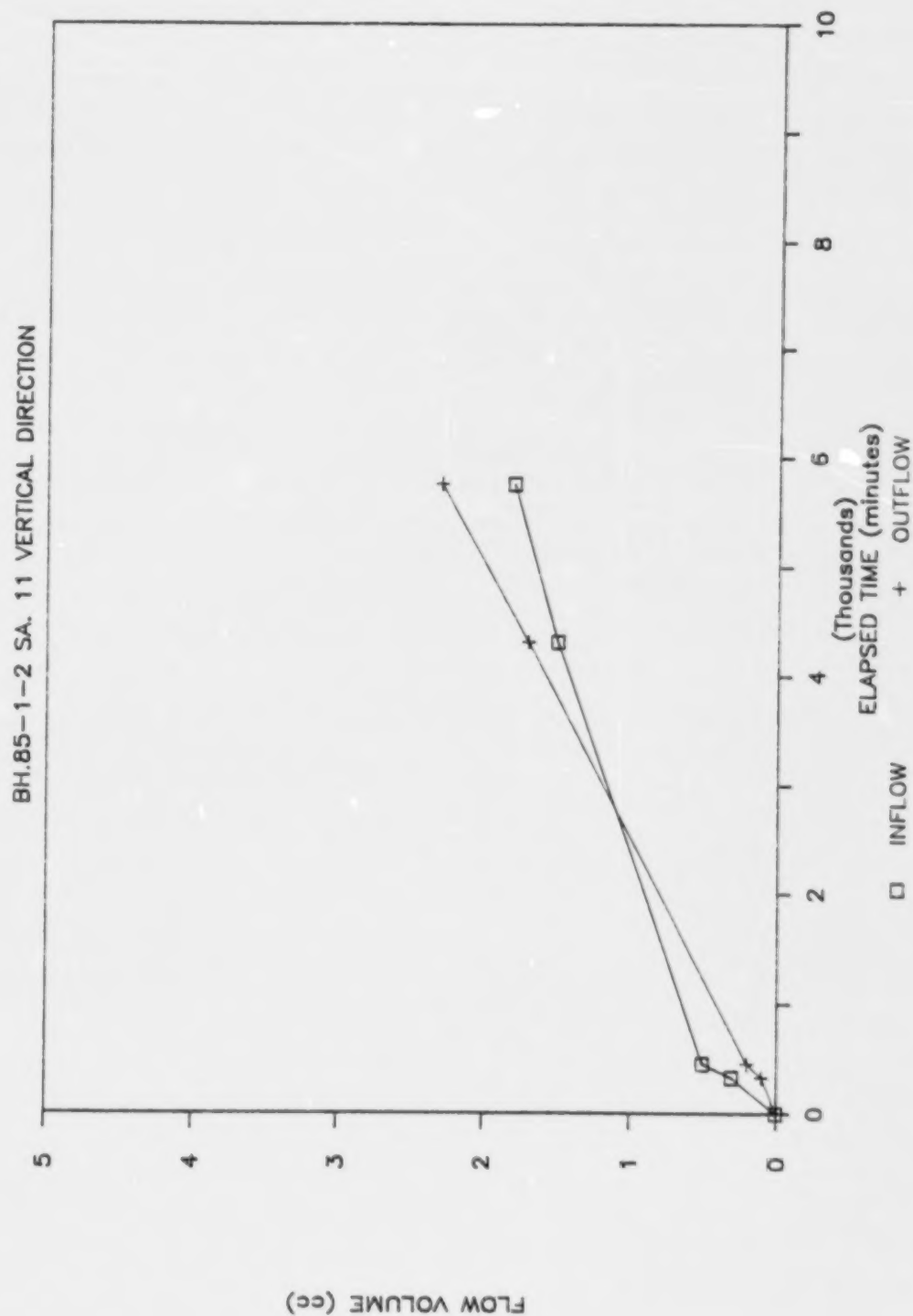
Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

PART 2		
MINUTES	INFLOW, k	
n/a	OUTFLOW, k	n/a cm/s
	AVERAGE, k	n/a cm/s
	AVERAGE, k USE FOR ANALYSES	1.44E-08 cm/s

Golder Associates

TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 2



Golder Associates

TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 3

BOREHOLE NUMBER 85-1-2 PROJECT 861-1121
 SAMPLE NUMBER 11 Horizontal Direction
 SAMPLE DEPTH 9.82 m (GLAL PROJECT 885-6W-8)
 SAMPLE TYPE Layered silty clay and clay with fine gravel

ORIGINAL: LENGTH cm	4.938	CONSOLIDATED: AREA cm ²	19.88	WET WEIGHT gm	289.8
DIAMETER cm	5.818	LENGTH cm	4.86	DRY WEIGHT gm	176.8
AREA cm ²	19.716	PRESSURE kPa	99.9	VOLUME WATER cc	33.8
VOLUME cc	97.201	HYDRAULIC GRADIENT (p/l)	19.96		

WATER CONTENT initial %	19.28	SPECIFIC GRAVITY	2.788	LIQUID LIMIT %	
WATER CONTENT final %	18.50	VOLUME SOLIDS cc	63.317	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	21.16	VOLUME VOIDS cc	33.884	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	17.75	VOID RATIO	0.535	SILT FRACTION (.075mm) %	
lb/ft ³	112.99	SATURATION %	99.693		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
137.8	138.9	1152	3.8	0.99

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
248.5	148.6	138.9	9.65	1877.818	99.9	189.5

DATE	CLOCK	ELAPSED TIME	ELAPSED TIME	INFLOW	OUTFLOW	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	min.	sec.	Vc cc	aVc cc	INFLOW cm/s	OUTFLOW cm/s
86-05-02	12:17	0	0	7.60	0.0	66.18	0.0
86-05-02	15:37	200	12000	7.70	0.10	66.00	0.10
86-05-05	08:35	4098	245800	9.40	1.80	63.90	2.20
86-05-05	11:38	4281	256860	9.55	1.95	63.80	2.30
86-05-05	13:17	4380	262800	9.60	2.00	63.70	2.40
86-05-05	15:24	4507	270420	9.70	2.10	63.60	2.50
86-05-06	08:53	5556	333360	10.10	2.50	63.20	2.90

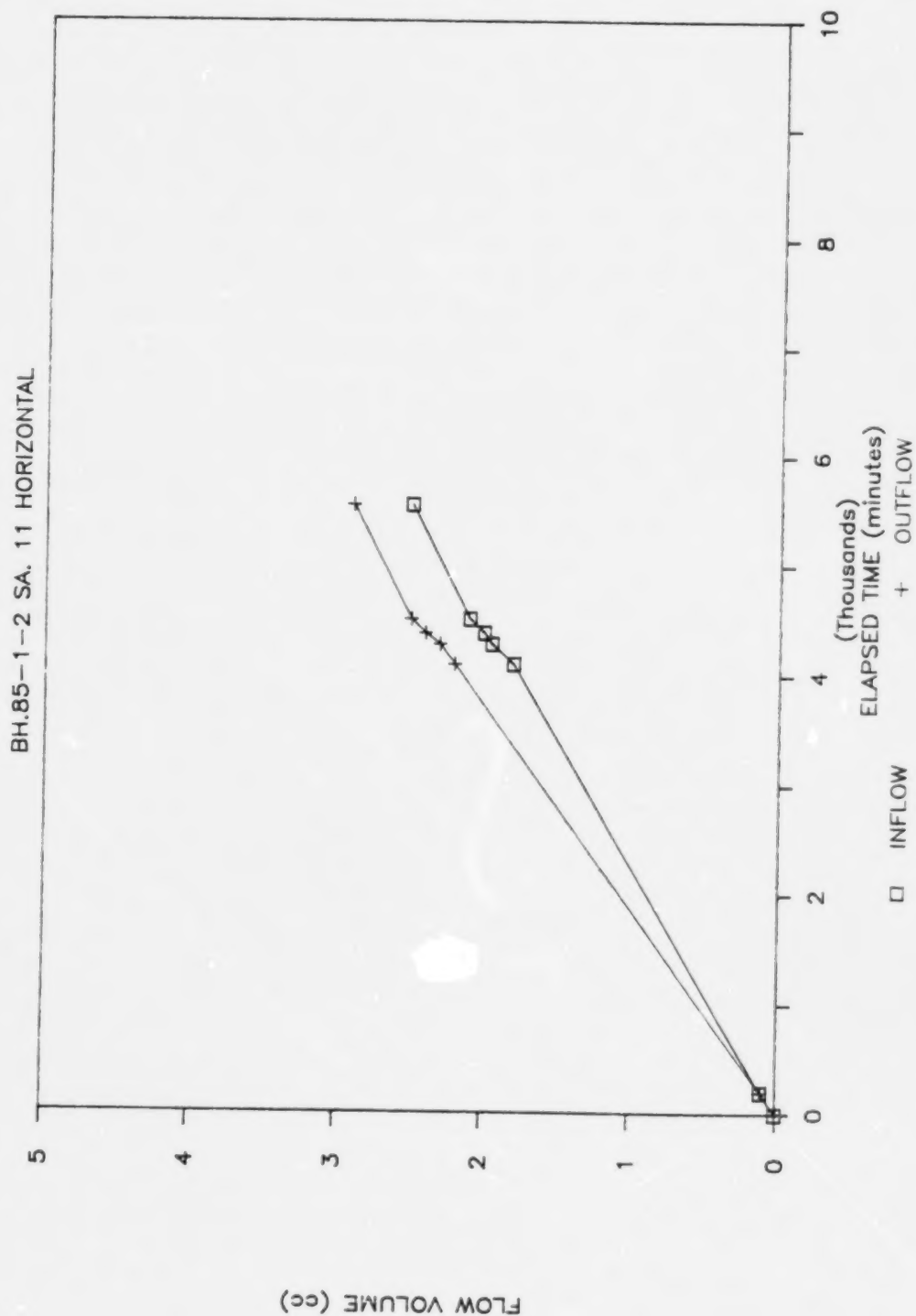
COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
5556	OUTFLOW, k	2.47E-08	3898	OUTFLOW, k	1.88E-08 cm/s
	AVERAGE, k	2.71E-08		AVERAGE, k	2.32E-08 cm/s
		2.59E-08			2.18E-08 cm/s
NOTES			PART 2		
			MINUTES	INFLOW, k	
Membrane sealed onto sample with vacuum grease.			1458	OUTFLOW, k	2.07E-08 cm/s
Consolidation prior to start of permeability test.				AVERAGE, k	2.07E-08 cm/s
0 time after 1440 minutes of permeability run.				AVERAGE, k USE FOR ANALYSES	2.07E-08 cm/s
Data by F.A.R.					

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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 4



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 5

BOREHOLE NUMBER 85-1-2 PROJECT 861-1121
 SAMPLE NUMBER 17 Vertical Direction
 SAMPLE DEPTH 15.72 m (GLAL PROJECT 885-5H-8)
 SAMPLE TYPE Silty clay with fine gravel, fissured

ORIGINAL: LENGTH cm	6.850	CONSOLIDATED: AREA cm ²	18.47	WET WEIGHT gm	276.2
DIAMETER cm	4.980	LENGTH cm	6.74	DRY WEIGHT gm	224.5
AREA cm ²	19.481	PRESSURE kPa	159.80	VOLUME WATER cc	51.7
VOLUME cc	133.443	HYDRAULIC GRADIENT (p/1)	19.50		

WATER CONTENT initial %	23.00	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	22.10	VOLUME SOLIDS cc	80.755	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.29	VOLUME VOIDS cc	52.687	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	16.50	VOID RATIO	0.652	SILT FRACTION (.075mm) %	
lb/ft ³	105.00	SATURATION %	98.126		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
359.7	199.8	2502	0.3	0.97

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
372.7	212.9	199.8	13.09	2467.525	159.8	172.9

DATE	CLOCK	ELAPSED TIME	ELAPSED TIME	INFLOW Vc	OUTFLOW Vc	OUTFLOW trns#3	DAILY PERMEABILITY RESULTS
YY-MM-DD	time	min.	sec.	cc	cc	cc	INFLOW cm/s
							OUTFLOW cm/s
86-05-08	14:23	0	0	not	1.0020	0.0	
86-05-08	16:46	143	0500	recorded	1.0032	0.04	1.36E-08
86-05-09	08:44	1101	66060		1.0068	0.17	6.09E-09
86-05-09	13:45	1402	84120		1.0092	0.26	1.29E-08
86-05-09	15:48	1525	91500		1.0100	0.28	1.05E-08
86-05-12	09:00	5437	326220		1.0217	0.70	4.05E-09
86-05-12	10:59	5556	333360		1.0228	0.74	1.50E-08

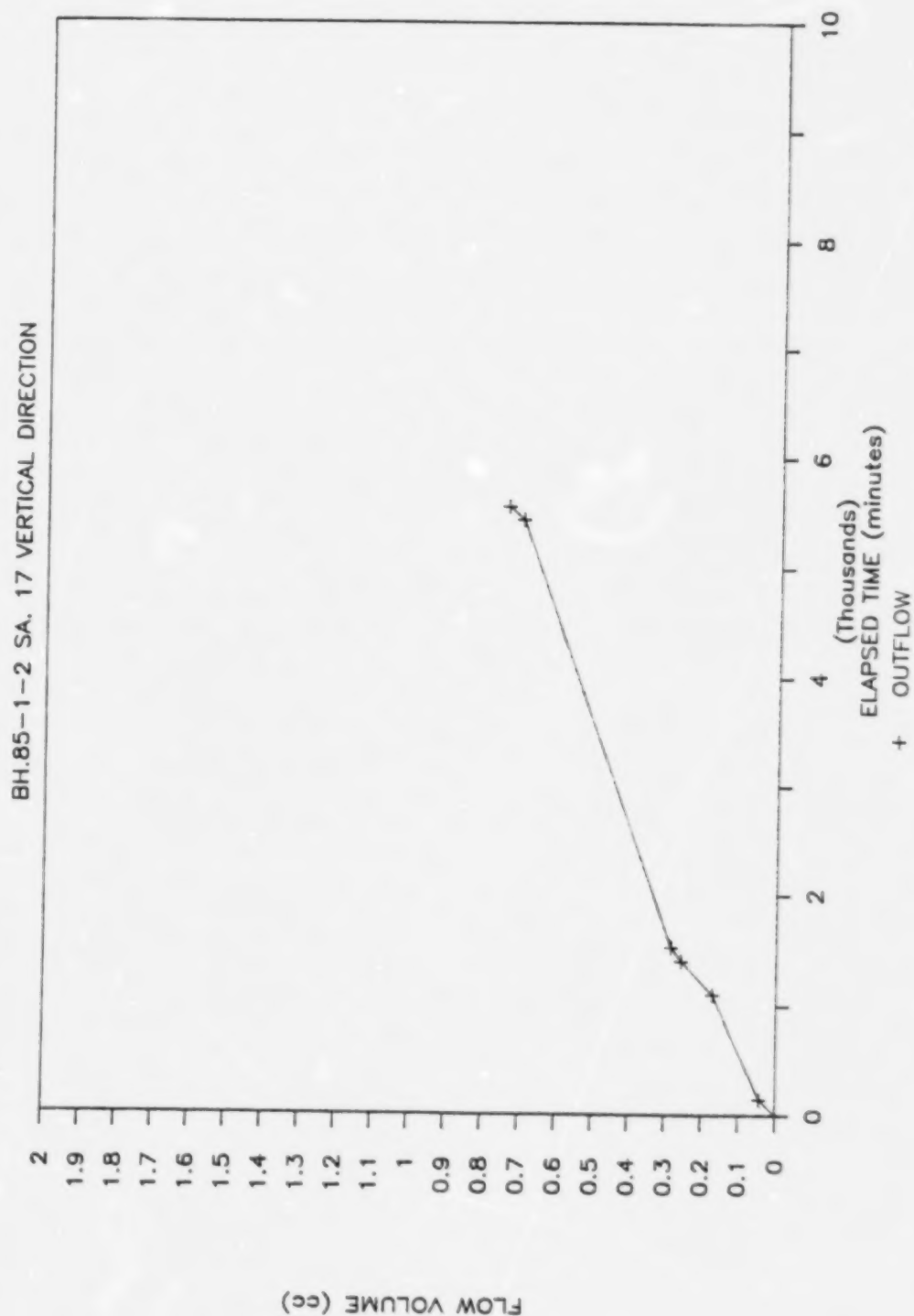
COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	cm/s
5556	OUTFLOW, k	1.05E-08	1382	OUTFLOW, k	7.98E-09
	AVERAGE, k	1.05E-08		AVERAGE, k	7.98E-09
NOTES			PART 2		
			MINUTES	INFLOW, k	cm/s
Membrane sealed onto sample with vacuum grease, Consolidation prior to start of permeability test, 0 time after 1440 minutes of permeability run. Data by F.A.R.			4031	OUTFLOW, k	5.15E-09
				AVERAGE, k	cm/s
			AVERAGE, k USE FOR ANALYSES	5.15E-09	cm/s

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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 6



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 7

BOREHOLE NUMBER 85-1-2 PROJECT 861-1121
 SAMPLE NUMBER 17 Horizontal Direction
 SAMPLE DEPTH 15.60 m (GLAL PROJECT 885-8H-8)
 SAMPLE TYPE Silty clay with fine gravel

ORIGINAL: LENGTH cm	4.930	CONSOLIDATED: AREA cm ²	21.24	WET WEIGHT gm	204.8
DIAMETER cm	5.240	LENGTH cm	4.89	DRY WEIGHT gm	165.8
AREA cm ²	21.568	PRESSURE kPa	159.90	VOLUME WATER cc	39.0
VOLUME cc	106.330	HYDRAULIC GRADIENT (p/1)	19.96		

WATER CONTENT initial %	23.50	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	22.40	VOLUME SOLIDS cc	59.640	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	18.88	VOLUME VOIDS cc	46.690	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	15.29	VOID RATIO	0.783	SILT FRACTION (.06mm) %	
lb/ft ³	97.32	SATURATION %	83.530		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
359.7	199.8	2467	2.1	0.98

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
369.3	209.5	199.8	9.65	2090.401	159.8	169.5

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW trns#2	OUTFLOW trns#1	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cm/s	cm/s
86-05-09	08:46	0	0	0.5647	0.0	1.0106	0.0
86-05-09	13:42	296	17760	0.5654	0.03	1.0131	0.09
86-05-09	15:53	427	25620	0.5657	0.05	1.0143	0.13
86-05-12	08:58	4332	259920	0.5817	0.02	1.0282	0.60
86-05-12	10:59	4453	267180	0.5818	0.02	1.0288	0.62

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
4453	OUTFLOW, k	8.73E-09	4026	OUTFLOW, k	7.51E-09 cm/s
	AVERAGE, k	8.73E-09		AVERAGE, k	4.82E-09 cm/s
					6.17E-09 cm/s
NOTES			PART 2		
			MINUTES	INFLOW, k	n/a cm/s
			n/a	OUTFLOW, k	n/a cm/s
				AVERAGE, k	cm/s
			AVERAGE, k	USE FOR ANALYSES	6.17E-09 cm/s

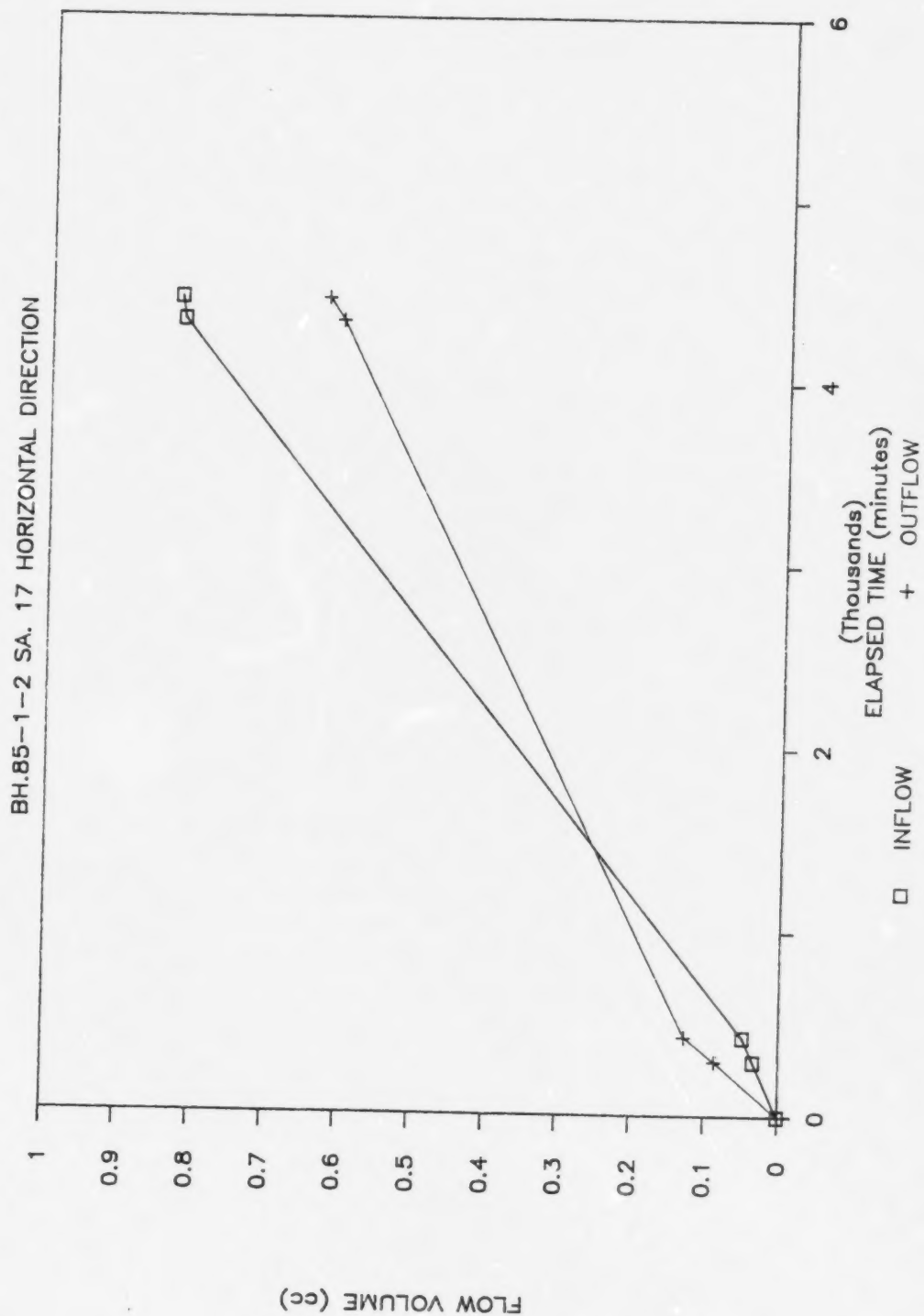
Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 8



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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 9

SHEET 1 OF 2

BOREHOLE NUMBER 85-1-2 PROJECT 861-1121
 SAMPLE NUMBER 26 Vertical Direction
 SAMPLE DEPTH 25.32 m (GLAL PROJECT #85-6H-8)
 SAMPLE TYPE Silty clay with fine gravel

ORIGINAL: LENGTH cm	6.720	CONSOLIDATED: AREA cm ²	18.17	WET WEIGHT gm	259.7
DIAMETER cm	4.940	LENGTH cm	6.54	DRY WEIGHT gm	200.3
AREA cm ²	19.169	PRESSURE kPa	259.8	VOLUME WATER cc	59.4
VOLUME cc	128.816	HYDRAULIC GRADIENT (p/l)	19.88		

WATER CONTENT initial %	29.70	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	24.70	VOLUME SOLIDS cc	72.050	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	19.76	VOLUME VOIDS cc	56.766	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	15.24	VOID RATIO	0.788	SILT FRACTION (.06mm) %	
lb/ft ³	96.99	SATURATION %	104.641		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure kPa	Back Pressure kPa	Test Duration min	Volume Water cc	B Value
459.6	199.8	1599	0.7	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure kPa	Head Pressure kPa	Back Pressure kPa	Effective Head Pressure kPa	Constant Ah	Effective Confining Pressure Top kPa	Base kPa
472.7	212.9	199.8	13.09	2426.920	259.8	272.8

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW	aVc	OUTFLOW	aVc	DAILY PERMEABILITY RESULTS
YY-MM-DD	time	TIME	TIME	Vc	cc	Vc	cc	INFLOW
		min.	sec.	cc		cc		OUTFLOW
								cm/s
								cm/s
86-05-09	08:36	0	0	18.00	0.0	57.20	0.0	
86-05-09	11:00	144	0640	18.00	0.00	57.20	0.00	0.00E+00
86-05-09	13:45	309	10540	18.10	0.10	57.20	0.00	2.72E-08
86-05-09	15:53	437	26220	18.10	0.10	57.10	0.10	0.00E+00
86-05-12	09:01	4345	260700	19.00	1.00	56.00	1.20	1.03E-08
86-05-12	10:57	4461	267660	19.00	1.00	56.00	1.20	0.00E+00

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW	MINUTES	INFLOW, k	7.51E-09	PART 1	MINUTES	INFLOW, k	1.00E-08	cm/s
	4461	OUTFLOW, k	9.55E-09		4024	OUTFLOW, k	1.23E-08	cm/s
		AVERAGE, k	8.53E-09			AVERAGE, k	1.12E-08	cm/s
NOTES				PART 2				
				MINUTES		INFLOW, k	n/a	cm/s
				n/a		OUTFLOW, k	n/a	cm/s
						AVERAGE, k	n/a	cm/s
						AVERAGE, k USE FOR ANALYSES	1.12E-08	cm/s

Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

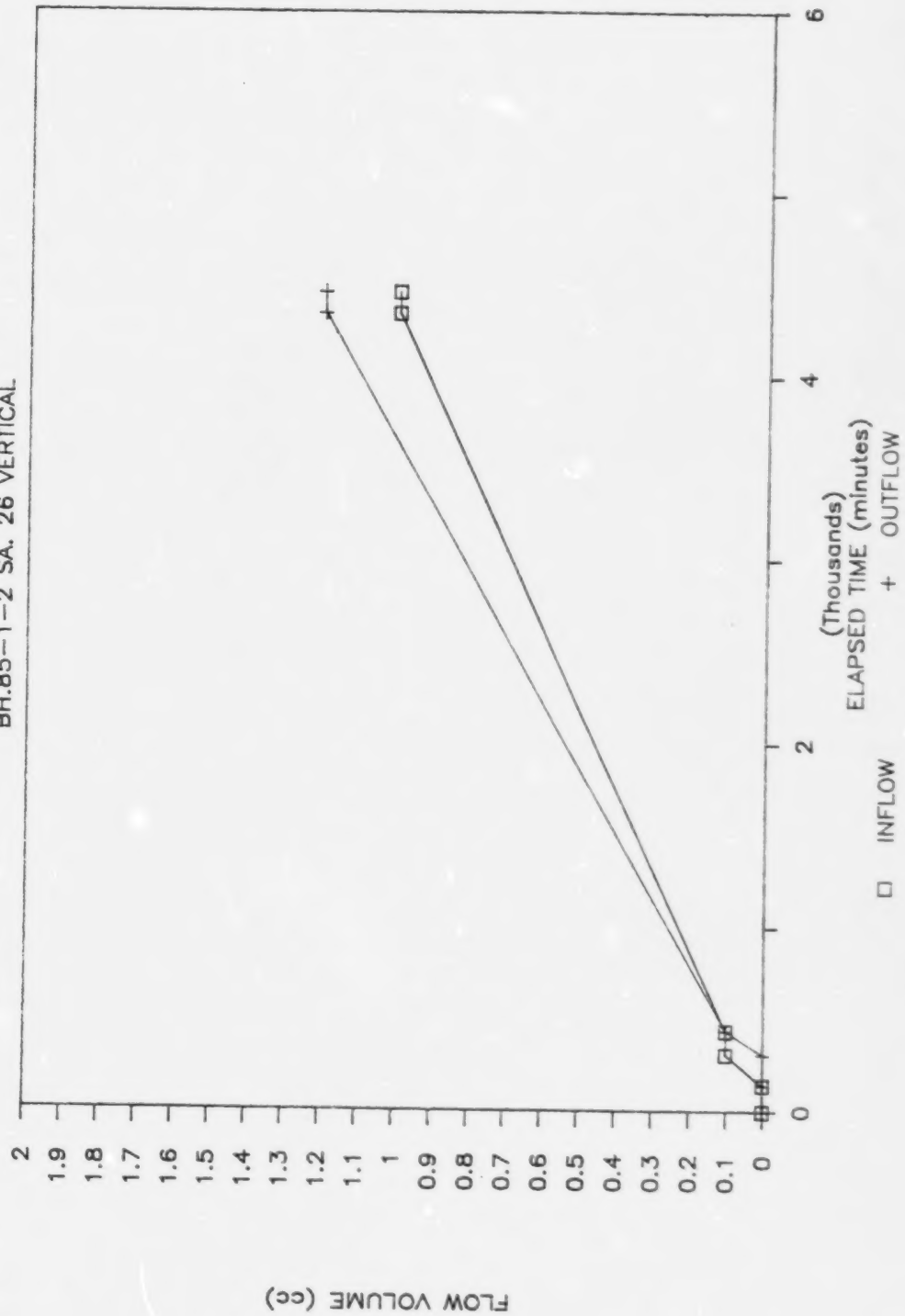
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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 10

BH.85-1-2 SA. 26 VERTICAL



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 11

SHEET 1 OF 2

BOREHOLE NUMBER 05-1-2
 SAMPLE NUMBER 26 Horizontal Direction
 SAMPLE DEPTH 25.22 m
 SAMPLE TYPE Silty clay with fine gravel

PROJECT 861-1121
 (GLAL PROJECT 085-0H-0)

ORIGINAL: LENGTH cm	6.660	CONSOLIDATED: AREA cm ²	17.02	WET WEIGHT gm	247.9
DIAMETER cm	4.780	LENGTH cm	6.49	DRY WEIGHT gm	193.8
AREA cm ²	17.947	PRESSURE kPa	259.8	VOLUME WATER cc	54.1
VOLUME cc	119.530	HYDRAULIC GRADIENT (p/l)	19.00		

WATER CONTENT initial %	27.90	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	23.60	VOLUME SOLIDS cc	69.712	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.33	VOLUME VOIDS cc	49.818	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	15.98	VOID RATIO	0.715	SILT FRACTION (.06mm) %	
lb/ft ³	101.19	SATURATION %	100.596		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
459.6	199.8	1386	0.1	0.97

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
472.0	212.2	199.8	12.40	2153.670	259.8	272.1

DATE	CLOCK	ELAPSED TIME	ELAPSED TIME	INFLOW Vc	aVc	OUTFLOW Vc	aVc	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	min.	sec.	cc	cc	cc	cc	INFLOW cm/s	OUTFLOW cm/s
86-05-09	08:35	0	0	51.26	0.0	45.60	0.0		
86-05-09	11:00	145	8700	51.10	0.10	45.70	0.10	3.46E-08	3.46E-08
86-05-09	13:46	311	18660	51.05	0.15	45.80	0.20	1.51E-08	3.03E-08
86-05-09	15:54	439	26340	51.00	0.20	45.90	0.30	1.96E-08	3.92E-08
86-05-12	08:55	4340	260400	49.80	1.40	46.60	1.00	1.54E-08	9.01E-09
86-05-12	10:55	4460	267600	49.75	1.45	46.65	1.05	2.09E-08	2.09E-08

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
4460	OUTFLOW, k	2.12E-08	4021	OUTFLOW, k	1.56E-08 cm/s
	AVERAGE, k	2.68E-08		AVERAGE, k	9.37E-09 cm/s
		2.40E-08			1.25E-08 cm/s

NOTES

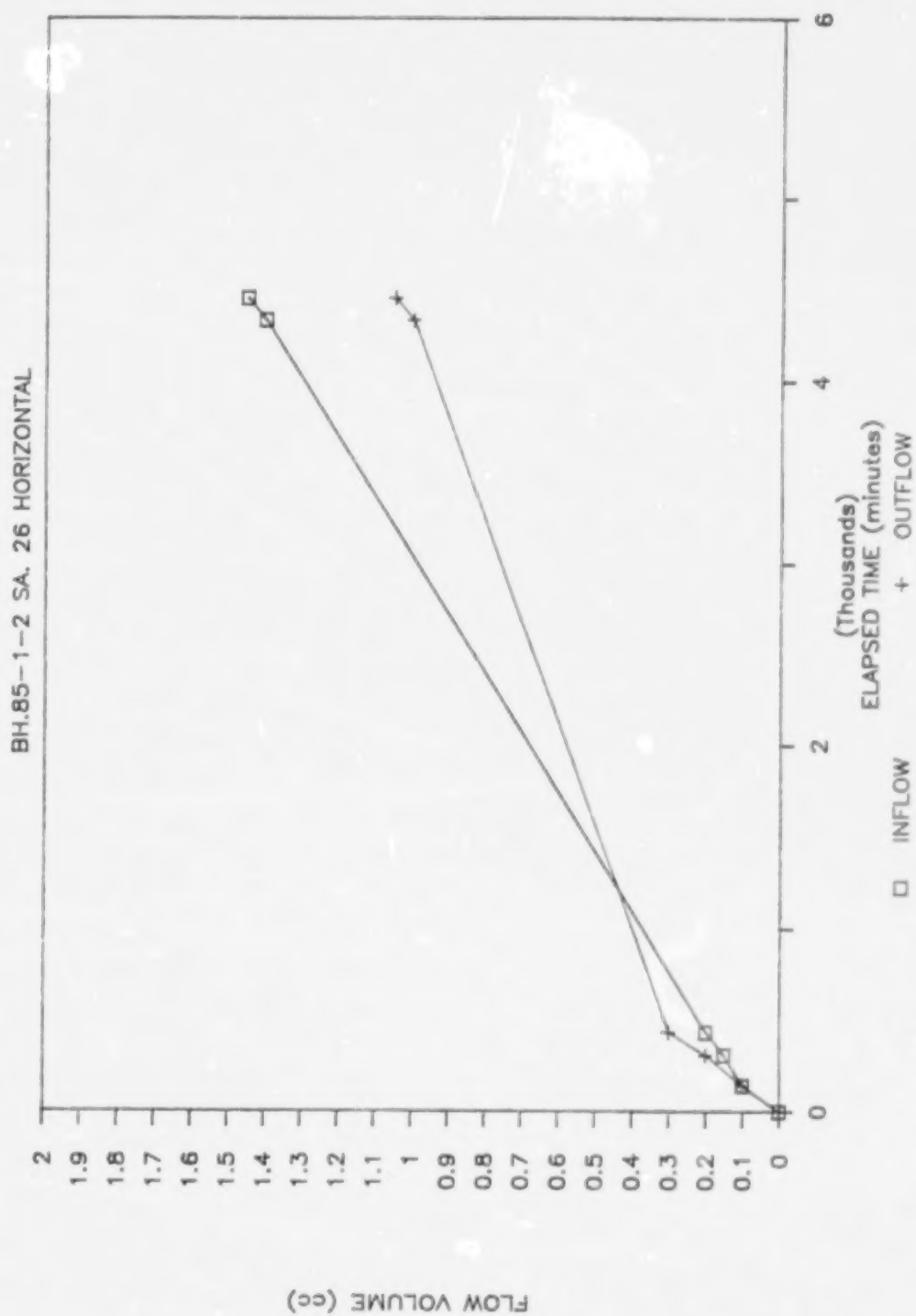
Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

PART 2		
MINUTES	INFLOW, k	
n/a	OUTFLOW, k	n/a cm/s
	AVERAGE, k	n/a cm/s
AVERAGE, k USE FOR ANALYSES		1.25E-08 cm/s

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 12



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 13

SHEET 1 OF 2

BOREHOLE NUMBER 85-1-B PROJECT 861-1121
 SAMPLE NUMBER 2 Vertical Direction
 SAMPLE DEPTH 4.17m IGAL PROJECT 85-SH-31
 SAMPLE TYPE Silty clay with fine gravel, fissured

ORIGINAL: LENGTH cm	6.590	CONSOLIDATED: AREA cm ²	18.96	WET WEIGHT gm	248.8
DIAMETER cm	4.980	LENGTH cm	6.50	DRY WEIGHT gm	198.8
AREA cm ²	19.481	PRESSURE kPa	48.23	VOLUME WATER cc	58.8
VOLUME cc	129.378	HYDRAULIC GRADIENT (p/1)	28.28		

WATER CONTENT initial %	38.80	SPECIFIC GRAVITY	2.788	LIQUID LIMIT %	
WATER CONTENT final %	32.78	VOLUME SOLIDS cc	88.633	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	19.88	VOLUME VOIDS cc	59.745	CLAY FRACTION (.200mm) %	
DRY UNIT WEIGHT kN/m ³	14.61	VOID RATIO	0.878	SILT FRACTION (.075mm) %	
lb/ft ³	93.82	SATURATION %	97.888		

SATURATION by BACK PRESSURE (achieved)

Cell	Back	Test	Volume	B
Pressure	Pressure	Duration	Water	Value
kPa	kPa	min	cc	
284.7	199.8	1531	1.7	8.99

PERMEABILITY TEST CONDITIONS

Cell	Head	Back	Effective	Effective		
Pressure	Pressure	Pressure	Head	Confining Pressure	Constant	Top
kPa	kPa	kPa	kPa		Am	kPa
261.1	212.9	199.8	12.18	2534.373	48.2	61.3

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW trans04	OUTFLOW trans03	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	INFLOW	OUTFLOW
		min.	SEC.	cc	cc	cm/s	cm/s
86-05-21	16:42	0	0	0.9111	0.0	0.7338	0.2
86-05-21	09:55	973	56388	0.8688	1.58	0.7545	0.74
86-05-21	14:22	1388	78832	0.8536	2.88	0.7614	0.98
86-05-21	16:47	1448	86488	0.8587	2.18	0.7646	1.18
86-05-21	08:52	5198	317488	0.8876	3.68	0.8875	2.62
86-05-21	17:18	5556	333368	0.8862	3.65	0.8889	2.67

COEFFICIENT of PERMEABILITY, k, cm/s

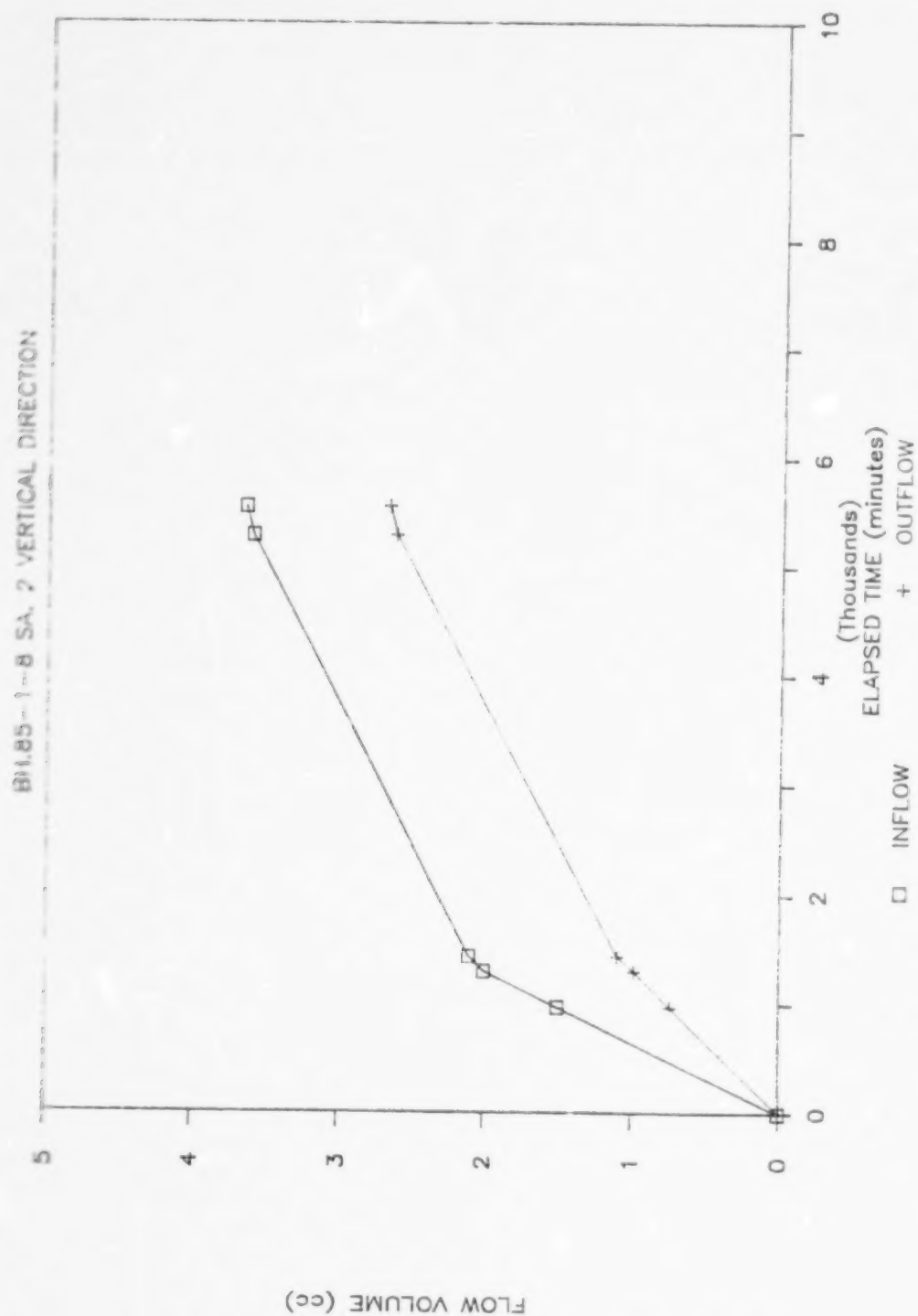
TOTAL FLOW	PART 1			
MINUTES	INFLOW, k	MINUTES	INFLOW, k	cm/s
5556	2.47E-08	4256	1.78E-08	cm/s
	AVERAGE, k		AVERAGE, k	cm/s
	3.18E-08		1.68E-08	cm/s

NOTES	PART 2		
	MINUTES	INFLOW, k	cm/s
	n/a	OUTFLOW, k	cm/s
		AVERAGE, k	cm/s
		1.68E-08	cm/s

Reebraze sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 3 time after 1448 minutes of permeability run.
 Data by F.A.R.

TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 14



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 15

SHEET 1 OF 2

BOREHOLE NUMBER 85-1-6 PROJECT 861-1121
 SAMPLE NUMBER 2 Horizontal Direction
 SAMPLE DEPTH 3.97 m (BLAL PROJECT 885-6H-8)
 SAMPLE TYPE Silty clay with fine gravel, fissured

=====

ORIGINAL: LENGTH cm	5.100	CONSOLIDATED: AREA cm ²	19.23	WET WEIGHT gm	197.7
DIAMETER cm	4.980	LENGTH cm	5.07	DRY WEIGHT gm	156.1
AREA cm ²	19.481	PRESSURE kPa	48.2	VOLUME WATER cc	41.6
VOLUME cc	99.352	HYDRAULIC GRADIENT (p/l)	19.41		

=====

WATER CONTENT initial %	26.68	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	29.10	VOLUME SOLIDS cc	56.151	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	19.51	VOLUME VOIDS cc	43.201	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	15.41	VOID RATIO	0.769	SILT FRACTION (.06mm) %	
lb/ft ³	98.88	SATURATION %	96.295		

=====

SATURATION by SACK PRESSURE (achieved)

Cell	Back	Test	Volume	B
Pressure	Pressure	Duration	Water	Value
kPa	kPa	min	cc	
106.7	199.8	1568	3.9	0.99

=====

PERMEABILITY TEST CONDITIONS

Cell	Head	Back	Effective	Effective		
Pressure	Pressure	Pressure	Head	Head	Constant	Confining Pressure
Va	kPa	kPa	Pressure	Pressure	At	Top Base
			kPa	kPa		kPa kPa
257.7	289.5	199.8	9.70	1903.175	48.2	57.9

=====

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW trns#2	OUTFLOW trns#1	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cm/s	cm/s
86-05-01	11:56	0	0	0.6413	0.0	0.0193	0.0
86-05-01	14:25	149	8940	0.6405	0.03	0.0224	0.11
86-05-01	16:41	295	17180	0.6408	0.05	0.0252	0.20
86-05-02	08:55	1259	75540	0.6299	0.41	0.0405	0.73
86-05-02	14:21	1585	95100	0.6293	0.44	0.0441	0.85
86-05-02	16:43	1727	103620	0.6288	0.45	0.0468	0.94
86-05-05	08:52	5576	334560	0.5969	1.54	0.0917	2.48

=====

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k	8.75E-09	MINUTES	INFLOW, k	5.93E-09
5576	OUTFLOW, k	2.51E-08	136	OUTFLOW, k	3.14E-08
	AVERAGE, k	1.69E-08		AVERAGE, k	1.86E-08

NOTES

 Membrane sealed onto sample with vacuum grease.
 Consolidation prior to start of permeability test.
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

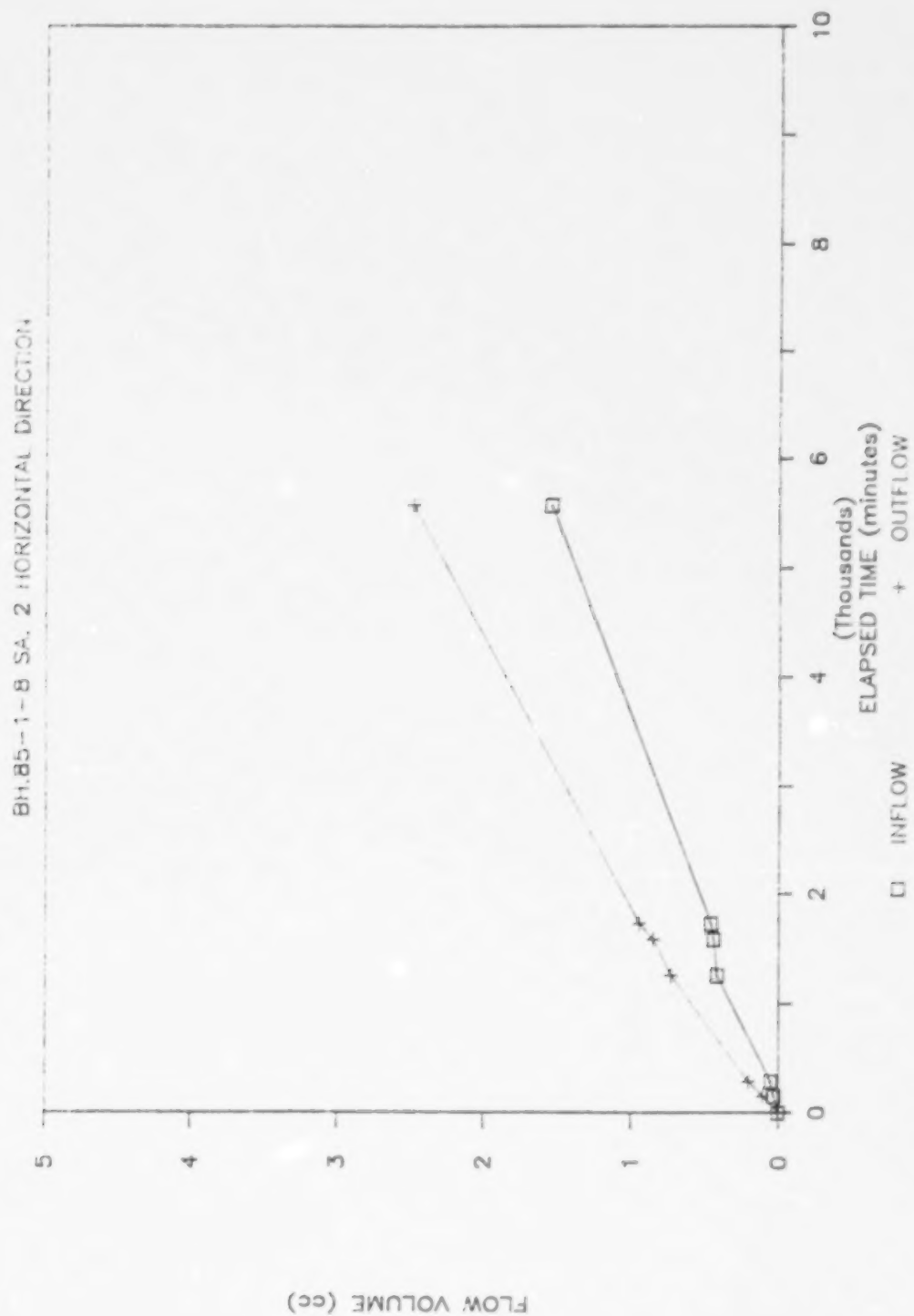
PART 2

MINUTES	INFLOW, k	1.25E-08	cm/s
5291	OUTFLOW, k	1.91E-09	cm/s
	AVERAGE, k	1.58E-08	cm/s
	AVERAGE, k	1.58E-08	cm/s

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 16



TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 17

BOREHOLE NUMBER 85-1-2 PROJECT 861-1121
 SAMPLE NUMBER 15 Vertical Direction
 SAMPLE DEPTH 18.72 m (BLAL PROJECT 885-DH-2)
 SAMPLE TYPE Silty clay with gravel, silt like

ORIGINAL: LENGTH cm	6.510	CONSOLIDATED: AREA cm ²	19.26	WET WEIGHT gm	262.4
DIAMETER cm	5.010	LENGTH cm	6.43	DRY WEIGHT gm	211.1
AREA cm ²	19.716	PRESSURE kPa	198.98	VOLUME WATER cc	51.3
VOLUME cc	128.352	HYDRAULIC GRADIENT (p/1)	19.45		

WATER CONTENT initial %	24.10	SPECIFIC GRAVITY	2.700	LIQUID LIMIT %	
WATER CONTENT final %	22.90	VOLUME SOLIDS cc	75.935	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.24	VOLUME VOIDS cc	52.417	CLAY FRACTION (0.002mm) %	
DRY UNIT WEIGHT kN/m ³	16.12	VOID RATIO	0.690	SILT FRACTION (0.075mm) %	
15/113	102.65	SATURATION %	97.965		

SATURATION BY BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
275.6	268.7	1157	1.3	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Effective Confining Pressure	Constant	Top	Base
kPa	kPa	kPa	kPa	kPa	cm	kPa	kPa
472.0	281.1	268.7	12.41	2429.879	198.9	283.3	

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW		OUTFLOW		DAILY PERMEABILITY RESULTS	
				time	time	Vc	ΔVc	Vc	ΔVc
YY-MM-DD	time	min.	sec.	cc	cc	cc	cc	cm/s	cm/s
86-05-29	06:37	0	0	3.12	0.2	71.20	0.2		
86-05-30	08:41	1444	06:40	3.70	0.60	70.40	0.80	1.53E-08	2.43E-08
86-05-30	14:37	1793	107500	3.80	0.70	70.20	1.00	1.26E-08	2.52E-08
86-05-30	16:35	1918	115000	3.85	0.75	70.20	1.00	1.76E-08	0.00E+00
86-05-31	14:07	3210	192600	4.40	1.30	69.70	1.50	1.87E-08	1.70E-08
86-06-02	10:18	5861	351600	5.50	2.40	68.60	2.60	1.82E-08	1.82E-08

COEFFICIENT OF PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
5861	OUTFLOW, k	1.70E-08	4417	OUTFLOW, k	1.79E-08 cm/s
	AVERAGE, k	1.70E-08		AVERAGE, k	1.79E-08 cm/s
NOTES			PART 2		
			MINUTES	INFLOW, k	n/a cm/s
			n/a	OUTFLOW, k	n/a cm/s
				AVERAGE, k	n/a cm/s
			AVERAGE, k USE FOR ANALYSIS	1.79E-08	cm/s

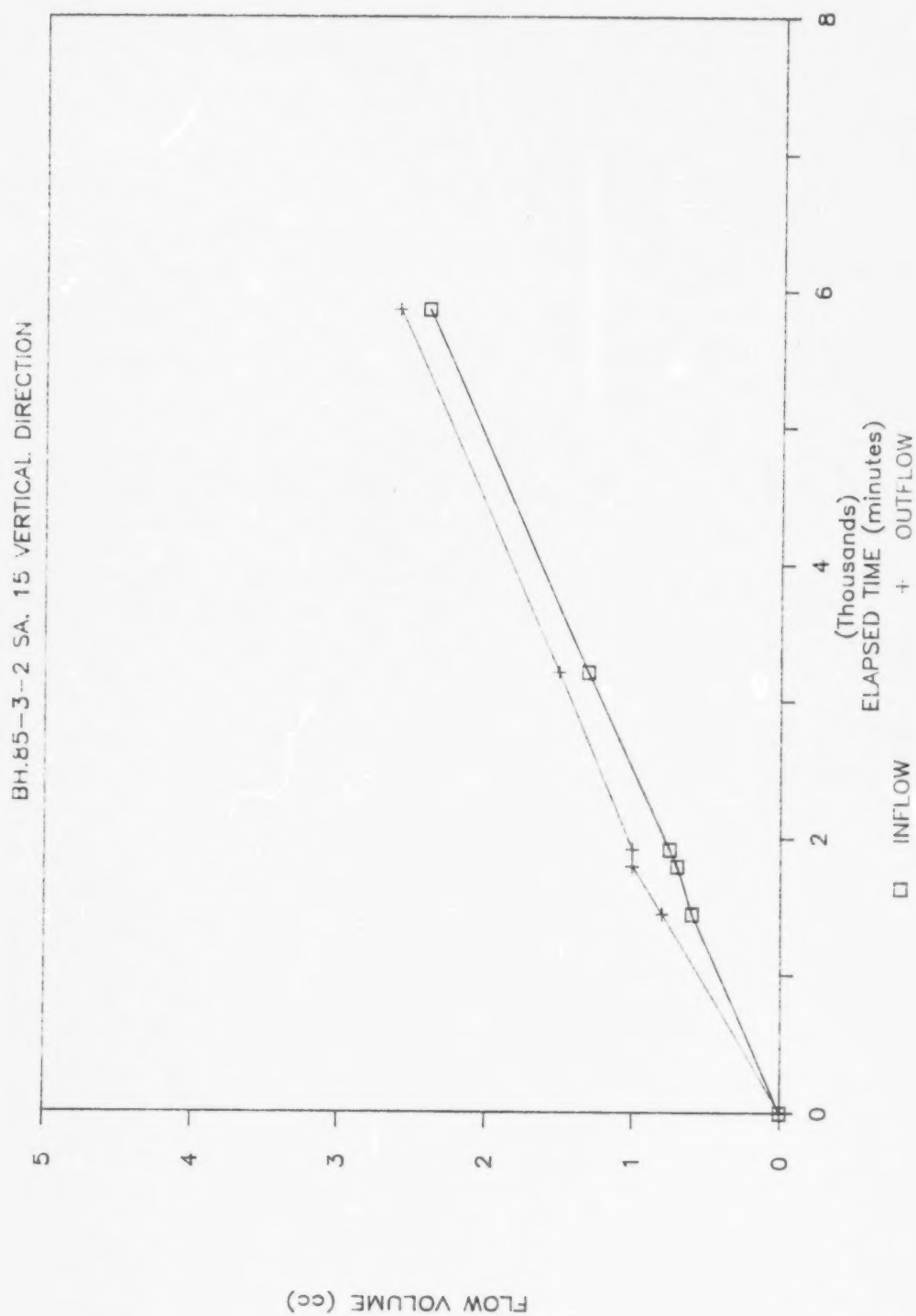
Membrane sealed onto sample with vacuum grease.
 Consolidation prior to start of permeability test.
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 18



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 19

SHEET 1 OF 2

BOREHOLE NUMBER 35-3-2 PROJECT 861-1121
 SAMPLE NUMBER 15 Horizontal Direction
 SAMPLE DEPTH 18.420 m (GLAL PROJECT 085-GH-8)
 SAMPLE TYPE Silty clay with fine gravel

ORIGINAL: LENGTH cm	5.500	CONSOLIDATED: AREA cm ²	18.63	WET WEIGHT gm	216.2
DIAMETER cm	4.930	LENGTH cm	5.43	DRY WEIGHT gm	176.2
AREA cm ²	19.291	PRESSURE kPa	190.20	VOLUME WATER cc	40.0
VOLUME cc	105.003	HYDRAULIC GRADIENT (p/l)	19.19		

WATER CONTENT initial %	22.70	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	21.40	VOLUME SOLIDS cc	63.381	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.18	VOLUME VOIDS cc	41.622	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	16.45	VOID RATIO	0.657	SILT FRACTION (.06mm) %	
lb/ft ³	104.71	SATURATION %	96.079		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	8 Value
kPa	kPa	min	cc	
117.8	110.9	403	0.2	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Effective Confining Pressure	Constant Ah	Top kPa	Base kPa
kPa	kPa	kPa	kPa				
331.4	141.2	130.9	10.34		1966.397	190.2	200.5

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW	OUTFLOW	DAILY PERMEABILITY RESULTS			
YY-MM-DD	time	TIME	TIME	Vc	aVc	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cc	cc	cm/s	cm/s
86-05-29	16:45	0	0	60.00	0.0	62.50	0.0		
86-05-30	08:17	950	57460	60.20	0.20	62.60	0.10	9.61E-09	4.80E-09
86-05-30	14:40	1315	75900	60.40	0.40	62.70	0.20	2.56E-08	1.29E-08
86-05-31	16:33	2060	172060	60.70	0.70	63.00	0.50	8.99E-09	8.09E-09
86-06-02	10:17	5372	322320	61.60	1.60	63.90	1.40	1.65E-08	1.65E-08

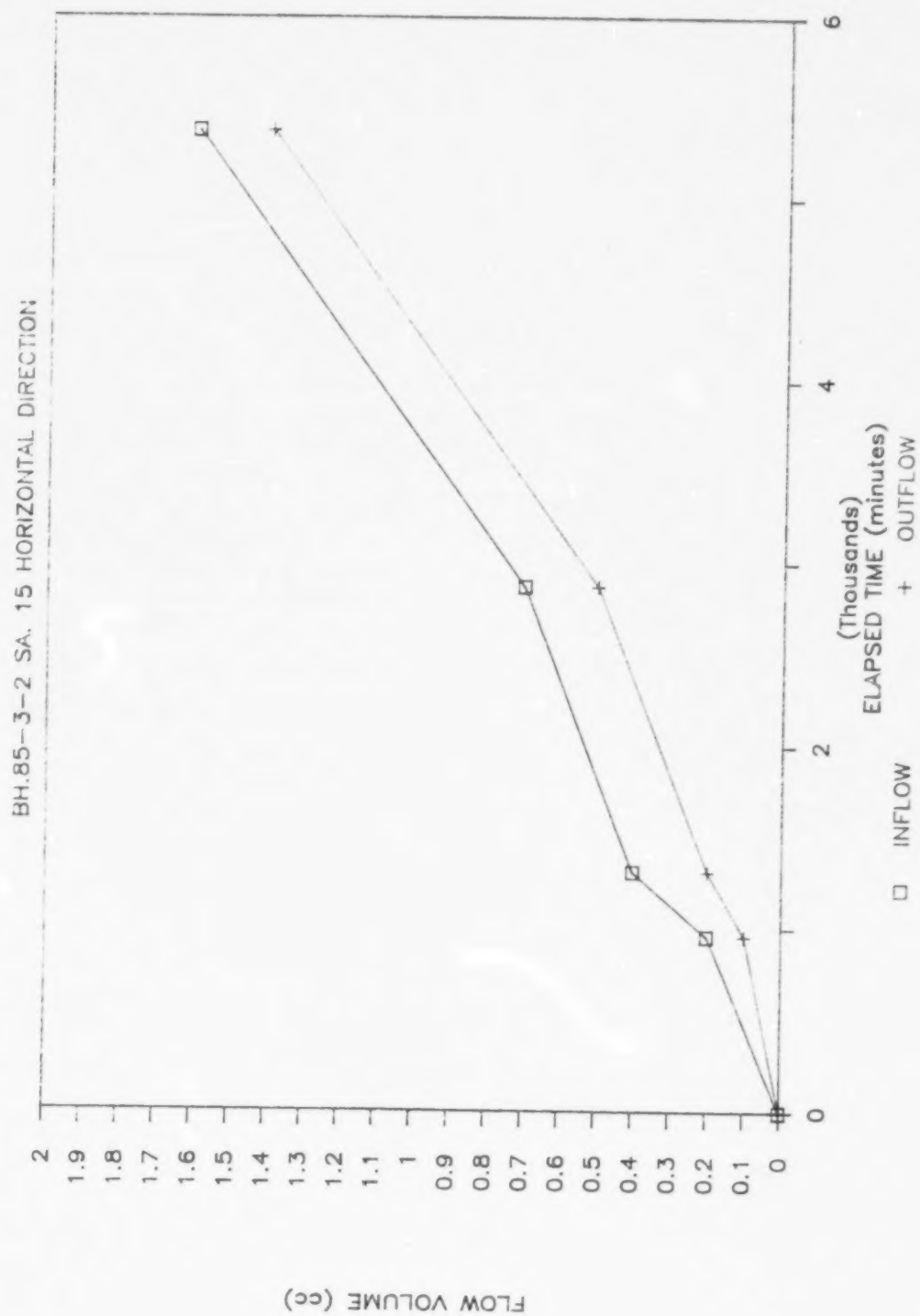
COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k	1.08E-08	MINUTES	INFLOW, k	1.20E-08 cm/s
5372	OUTFLOW, k	1.06E-08	1910	OUTFLOW, k	9.64E-09 cm/s
	AVERAGE, k	1.08E-08		AVERAGE, k	1.08E-08 cm/s
NOTES			PART 2		
-----			MINUTES	INFLOW, k	1.65E-08 cm/s
Membrane sealed onto sample with vacuum grease,			2504	OUTFLOW, k	1.65E-08 cm/s
Consolidation prior to start of permeability test.				AVERAGE, k	1.65E-08 cm/s
0 time after 1440 minutes of permeability run.			AVERAGE, k USE FOR ANALYSES 1.65E-08 cm/s		
Data by F.A.R.					

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 20



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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 21

BOREHOLE NUMBER 35-2 2 PROJECT 861-1121
 SAMPLE NUMBER 20 Vertical Direction
 SAMPLE DEPTH 26.35 m (GLAL PROJECT 085-6H-B)
 SAMPLE TYPE Silty clay with fine gravel

ORIGINAL: LENGTH cm	6.273	CONSOLIDATED: AREA cm ²	19.42	WET WEIGHT gm	230.3
DIAMETER cm	4.973	LENGTH cm	6.11	DRY WEIGHT gm	168.1
AREA cm ²	19.403	PRESSURE kPa	270.09	VOLUME WATER cc	62.2
VOLUME cc	121.654	HYDRAULIC GRADIENT (p/l)	19.06		

WATER CONTENT initial %	36.90	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	35.90	VOLUME SOLIDS cc	60.468	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	18.56	VOLUME VOIDS cc	61.186	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	13.56	VOID RATIO	1.012	SILT FRACTION (.06mm) %	
lb/ft ³	86.29	SATURATION %	101.657		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
275.6	266.7	2557	4.0	0.97

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
550.5	280.4	268.7	11.71	2281.332	270.1	281.8

DATE	CLOCK	ELAPSED TIME	ELAPSED TIME	INFLOW Vc	aVc	OUTFLOW Vc	aVc	DAILY PERMEABILITY RESULTS
YY-MM-DD	time	min.	sec.	cc	cc	cc	cc	INFLOW cm/s
								OUTFLOW cm/s
86-06-06	13:08	0	0	18.75	0.0	59.20	0.0	
86-06-06	14:48	220	13200	19.70	0.05	59.20	0.00	1.05E-08
86-06-07	11:56	1360	82080	18.35	0.40	58.40	0.00	1.41E-08
86-06-09	08:36	4048	242880	17.60	1.15	57.00	2.20	1.29E-08

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
4048	OUTFLOW, k	1.88E-08	1148	OUTFLOW, k	1.41E-08 cm/s
	AVERAGE, k	1.88E-08		AVERAGE, k	3.22E-08 cm/s
					2.32E-08 cm/s

NOTES

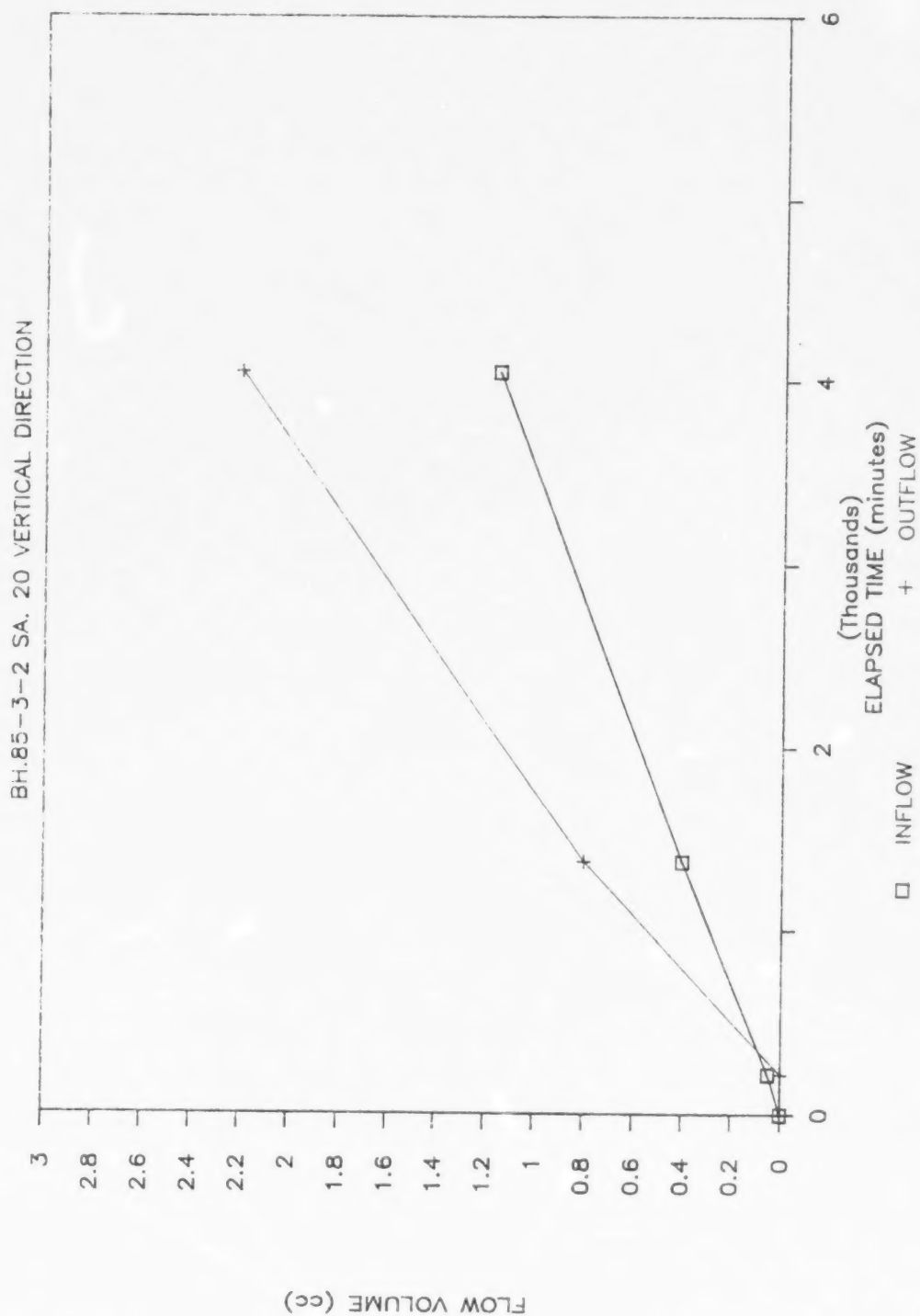
Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

PART 2		
MINUTES	INFLOW, k	
2600	OUTFLOW, k	1.29E-08 cm/s
	AVERAGE, k	2.42E-08 cm/s
		1.96E-08 cm/s
	AVERAGE, k USE FOR ANALYSES	1.06E-08 cm/s

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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 22



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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 23

SHEET 1 OF 2

BOREHOLE NUMBER 85-3-2 PROJECT 861-1121
 SAMPLE NUMBER 20 Horizontal Direction
 SAMPLE DEPTH 26.35 m (6LAL PROJECT #85-6H-8)
 SAMPLE TYPE Silty clay with fine gravel

ORIGINAL: LENGTH cm	5.690	CONSOLIDATED: AREA cm ²	19.33	WET WEIGHT gm	229.6
DIAMETER cm	5.090	LENGTH cm	5.55	DRY WEIGHT gm	175.4
AREA cm ²	20.351	PRESSURE kPa	270.09	VOLUME WATER cc	54.2
VOLUME cc	115.796	HYDRAULIC GRADIENT (p/1)	19.77		

WATER CONTENT initial %	30.90	SPECIFIC GRAVITY	2.700	LIQUID LIMIT %	
WATER CONTENT final %	30.00	VOLUME SOLIDS cc	63.094	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	19.44	VOLUME VOIDS cc	52.703	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	14.85	VOID RATIO	0.835	SILT FRACTION (.06mm) %	
lb/ft ³	94.52	SATURATION %	102.841		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
275.6	268.7	2539	3.3	0.97

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
549.8	279.7	268.7	11.02	2174.197	270.1	281.1

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW	OUTFLOW	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	min.	sec.	Vc cc	aVc cc	INFLOW cm/s	OUTFLOW cm/s
86-06-06	16:36	0	0	2.90	0.0		
86-06-07	11:53	1157	69420	3.30	0.40	1.47E-08	7.35E-09
86-06-09	08:35	3839	230340	4.30	1.40	1.59E-08	2.06E-08
86-06-09	18:25	3949	236940	4.40	1.50	3.87E-08	3.87E-08

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
3949	2.22E-08		2682	1.59E-08	cm/s
	OUTFLOW, k	2.22E-08		2.06E-08	cm/s
	AVERAGE, k	2.22E-08		1.82E-08	cm/s
NOTES			PART 2		
			MINUTES	INFLOW, k	
Membrane sealed onto sample with vacuum grease,			2792	1.60E-08	cm/s
Consolidation prior to start of permeability test,				2.13E-08	cm/s
0 time after 1440 minutes of permeability run.				1.90E-08	cm/s
Data by F.A.R.			AVERAGE, k USE FOR ANALYSES	1.90E-08	cm/s

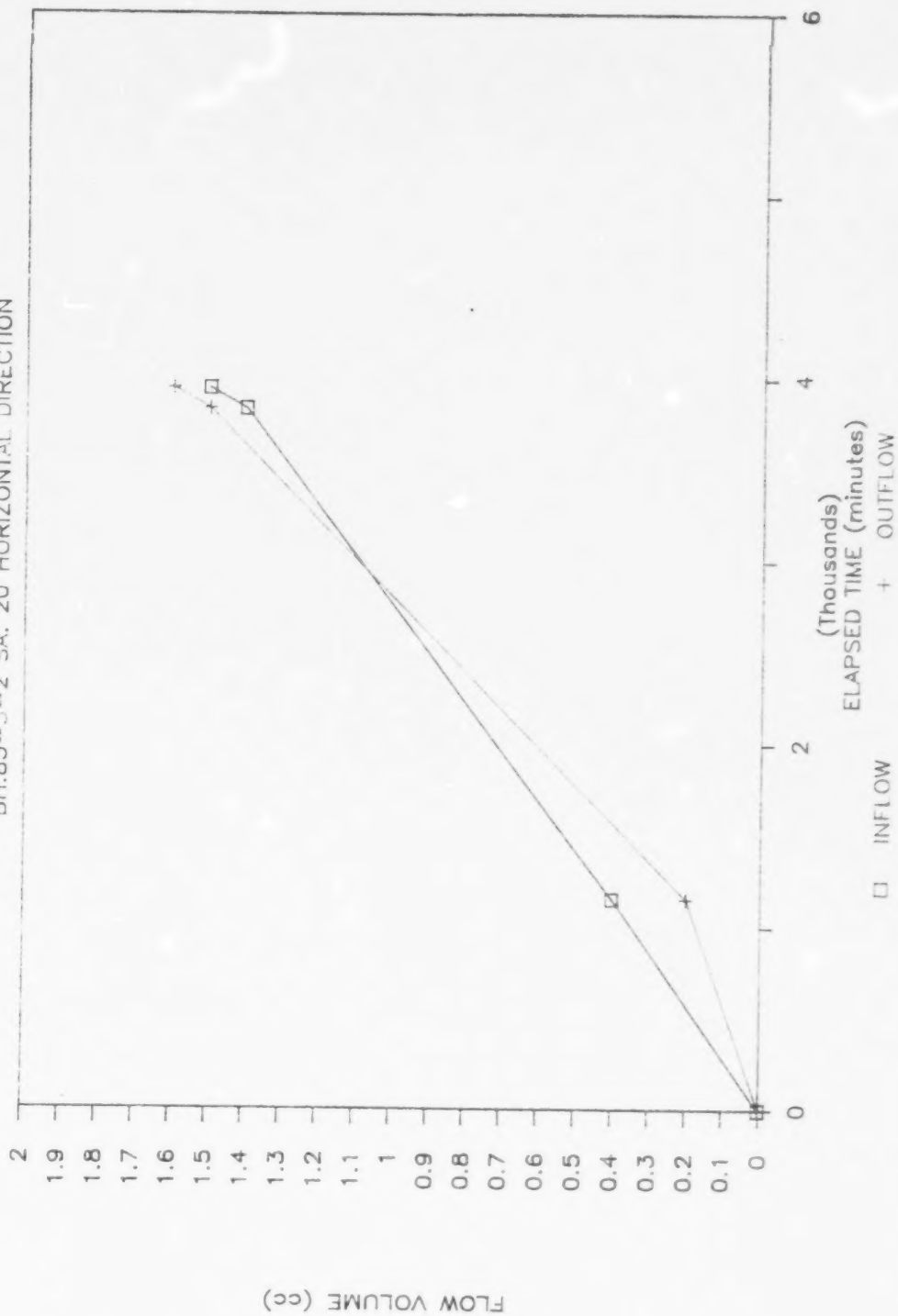
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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 24

BH.85--3--2 SA. 20 HORIZONTAL DIRECTION



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 25

SHEET 1 OF 2

BOREHOLE NUMBER 85-B-8 PROJECT 861-1121
 SAMPLE NUMBER 2 Vertical Direction
 SAMPLE DEPTH 4.89 m (6LAL PROJECT 085-GH-B)
 SAMPLE TYPE Clayey silt to silty clay occasional silt seams pockets of gypsum

ORIGINAL: LENGTH cm	5.780	CONSOLIDATED: AREA cm ²	19.41	WET WEIGHT gm	232.4
DIAMETER cm	5.030	LENGTH cm	5.71	DRY WEIGHT gm	198.5
AREA cm ²	19.874	PRESSURE kPa	44.78	VOLUME WATER cc	33.9
VOLUME cc	114.871	HYDRAULIC GRADIENT (p/1)	19.46		

WATER CONTENT initial %	17.10	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	18.98	VOLUME SOLIDS cc	71.403	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	19.83	VOLUME VOID cc	43.468	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	16.93	VOID RATIO	0.609	SILT FRACTION (.06mm) %	
lb/ft ³	107.79	SATURATION %	77.919		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
137.2	138.9	1440	2.7	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Effective Confining Pressure	Constant Ah	Top kPa	Base kPa
kPa	kPa	kPa	kPa				
186.7	141.9	138.9	11.02		2183.195	44.8	55.8

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW	OUTFLOW	DAILY PERMEABILITY RESULTS			
YY-MM-DD	time	TIME	TIME	Vc	aVc	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cc	cc	cm/s	cm/s
86-06-06	09:11	0	0	71.00	0.0	64.20	0.0		
86-06-06	13:09	239	14280	71.10	0.10	64.80	0.00	1.83E-08	0.00E+00
86-06-06	16:49	458	27480	71.20	0.20	64.80	0.00	1.98E-08	0.00E+00
86-06-07	11:57	1606	96360	71.20	0.20	64.30	0.30	0.00E+00	1.14E-08
86-06-09	08:37	4286	257160	71.30	0.30	64.40	0.40	1.63E-09	1.63E-09
86-06-09	17:05	4794	287640	71.40	0.40	64.50	0.50	0.58E-09	0.58E-09
86-06-10	06:42	5731	343860	71.50	0.50	64.70	0.70	4.65E-09	9.30E-09

COEFFICIENT of PERMEABILITY, k, cm/s

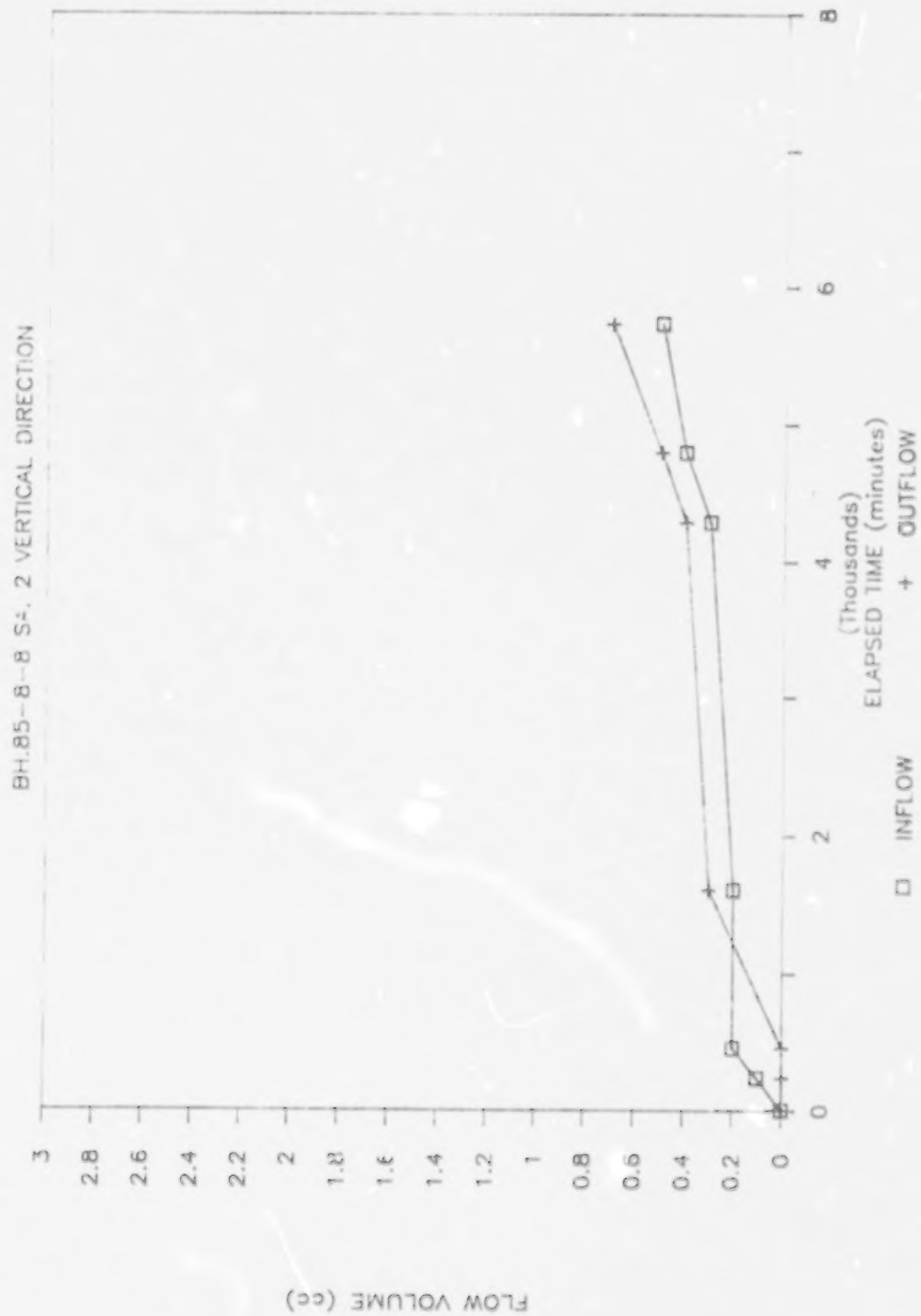
TOTAL FLOW				PART 1			
MINUTES	INFLOW, k			MINUTES	INFLOW, k		
5731	OUTFLOW, k	5.15E-09		4048	OUTFLOW, k	4.31E-09	cm/s
	AVERAGE, k	5.15E-09			AVERAGE, k	3.23E-09	cm/s
NOTES				PART 2			
				MINUTES	INFLOW, k		
				1445	OUTFLOW, k	9.05E-09	cm/s
					AVERAGE, k	7.54E-09	cm/s
					AVERAGE, k USE FOR ANALYSES	7.54E-09	cm/s

Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 26



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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 27

BOREHOLE NUMBER 05-8-8 PROJECT 861-1121
 SAMPLE NUMBER 2 Horizontal Direction
 SAMPLE DEPTH 3.99 m (GLAL PROJECT 005-GH-9)
 SAMPLE TYPE Clayey silt to silty clay occasional gypsum pockets

ORIGINAL: LENGTH cm	5.130	CONSOLIDATED: AREA cm ²	19.95	WET WEIGHT gm	706.2
DIAMETER cm	5.070	LENGTH cm	5.10	DRY WEIGHT gm	163.2
AREA cm ²	20.191	PRESSURE kPa	44.00	VOLUME WATER cc	47.0
VOLUME cc	103.501	HYDRAULIC GRADIENT (p/1)	20.55		

WATER CONTENT initial %	26.30	SPECIFIC GRAVITY	2.700	LIQUID LIMIT %	
WATER CONTENT final %	27.40	VOLUME SOLIDS cc	50.705	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	19.51	VOLUME VOIDS cc	44.876	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	15.45	VOID RATIO	0.764	SILT FRACTION (.075mm) %	
lb/ft ³	98.34	SATURATION %	95.753		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
275.6	268.7	1620	5.3	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant	Effective Confining Pressure	Top	Base
kPa	kPa	kPa	kPa	mm	kPa	kPa	kPa
323.0	279.0	268.7	10.33	2103.687	44.0	55.1	

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW	OUTFLOW	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cm/s	cm/s
86-06-11	08:39	0	0	16.10	0.0	59.00	0.0
86-06-11	10:26	107	6420	16.10	0.20	59.10	0.18
86-06-11	12:00	201	12060	16.00	0.10	59.20	0.20
86-06-11	13:24	285	17100	16.00	0.10	59.40	0.40
86-06-11	15:13	394	23640	16.00	0.10	59.50	0.50
86-06-11	16:47	488	29280	15.90	0.20	59.50	0.50
86-06-12	09:21	1482	88920	15.40	0.70	59.90	0.90
86-06-12	15:00	1821	109260	15.00	1.10	60.00	1.00
86-06-13	12:34	2995	179700	14.60	1.50	60.40	1.40

COEFFICIENT of PERMEABILITY, k, cm/s

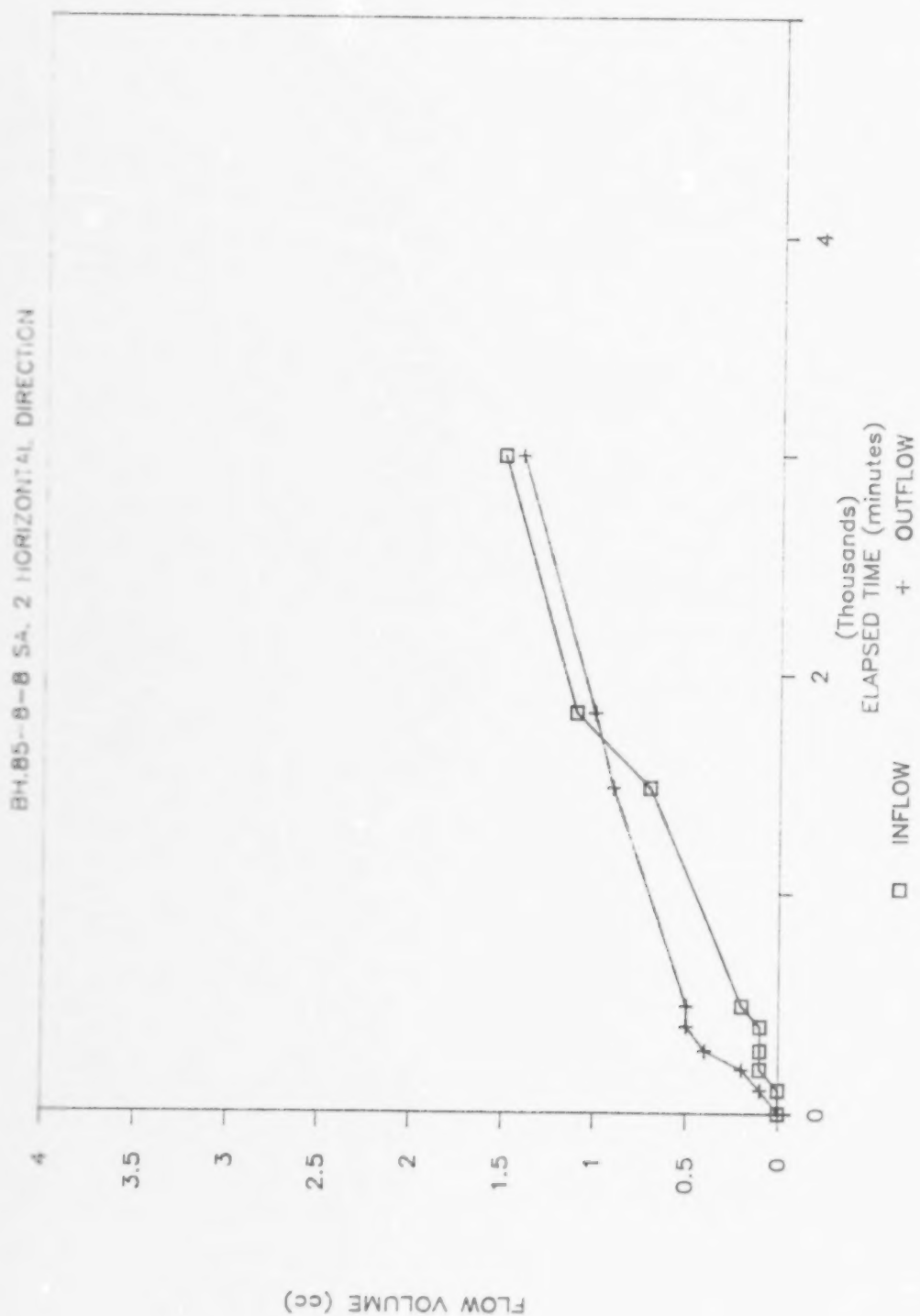
TOTAL FLOW			PART 1		
MINUTES	INFLOW, k	3.20E-08	MINUTES	INFLOW, k	2.10E-08
2995	OUTFLOW, k	3.20E-08	2507	OUTFLOW, k	1.45E-08
	AVERAGE, k	3.20E-08		AVERAGE, k	1.77E-08
NOTES			PART 2		
			MINUTES	INFLOW, k	n/a
			n/a	OUTFLOW, k	n/a
				AVERAGE, k	n/a
			AVERAGE, k	USE FOR ANALYSES	1.77E-08

Membrane sealed onto sample with vacuum grease.
 Consolidation prior to start of permeability test.
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 28



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SHEET 1 OF 2

BOREHOLE NUMBER	85-9-B	PROJECT	B61-1121
SAMPLE NUMBER	6 Vertical Direction		
SAMPLE DEPTH	22.43 m		(GLAL PROJECT 085-6H-8)
SAMPLE TYPE	Silty clay trace gravel occasional silt seams		

WATER CONTENT initial %	28.90	SPECIFIC GRAVITY	2.700	LIQUID LIMIT %
WATER CONTENT final %	28.70	VOLUME SOLIDS cc	70.309	PLASTIC INDEX %
UNIT WEIGHT kN/m ³	18.94	VOLUME VOIDS cc	60.076	CLAY FRACTION (.002mm) %
DRY UNIT WEIGHT kN/m ³	14.70	VOID RATIO	0.854	SILT FRACTION (.075mm) %
lb/ft ³	93.54	SATURATION %	94.831	

Cell	Back	Test	Volume	B
Pressure	Pressure	Duration	Water	Value
kPa	kPa	min	cc	
275.6	268.7	2520	1.4	0.50

Cell Pressure kPa	Head Pressure kPa	Back Pressure kPa	Effective Heed Pressure kPa	Constant At	Effective Confining Pressure Top kPa	Base kPa
511.9	281.8	266.7	13.89	2479.812	238.1	243.2

DATE YY-MM-DD	CLOCK time	ELAPSED	ELAPSED	INFLOW		OUTFLOW		DAILY PERMEABILITY RESULTS	
		TIME	TIME	Vc	aVc	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cc	cc	cm/s	cm/s
86-06-13	10:53	0	0	51.00	0.0	59.20	0.0		
86-06-13	14:13	200	12000	51.90	0.10	59.10	0.10	2.21E-00	2.21E-00
86-06-13	16:11	319	19050	52.00	0.20	59.00	0.20	3.74E-00	3.74E-00
86-06-13	16:50	357	21420	52.00	0.20	59.00	0.20	0.00E+00	0.00E+00
86-06-14	15:23	1710	102600	52.00	0.00	59.40	0.00	1.96E-00	1.96E-00
86-06-15	11:17	2904	174240	53.20	1.40	56.00	1.20	2.22E-00	1.43E-00
86-06-16	00:38	4185	251100	53.00	2.00	57.40	1.80	2.07E-00	2.07E-00

TOTAL FLOW			PART 1		
MINUTES	INFLOW,k	1.91E-08	MINUTES	INFLOW,k	2.05E-08 CM/S
4185	OUTFLOW,k	1.91E-08	1510	OUTFLOW,k	2.05E-08 CM/S
	AVERAGE,k	1.91E-08		AVERAGE,k	2.05E-08 CM/S

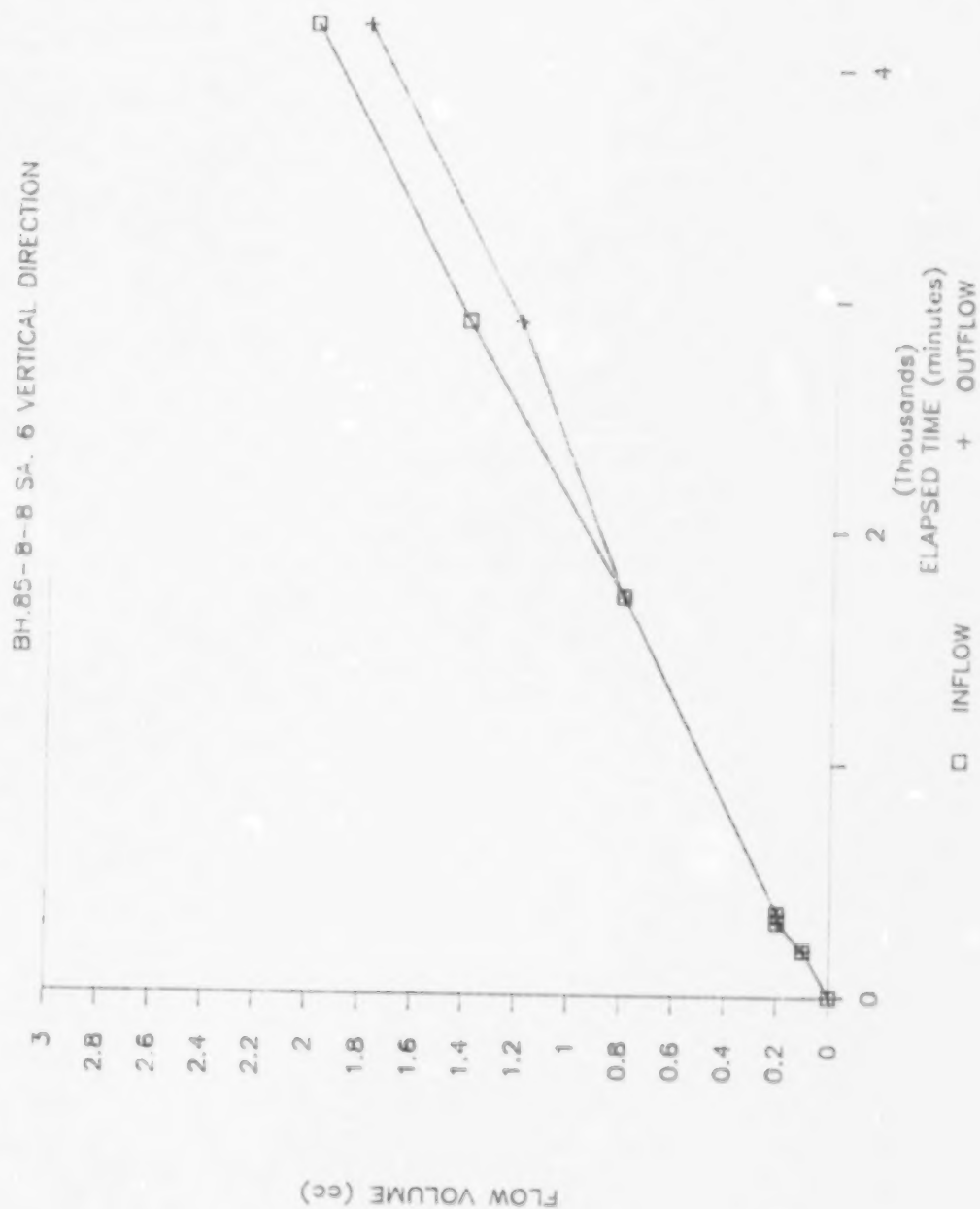
PART 2

-----	MINUTES	INFLOW,k	2.14E-08	cm/s
Membrane sealed onto sample with vacuum grease,	2475	OUTFLOW,k	1.78E-08	cm/s
Consolidation prior to start of permeability test,		AVERAGE,k	1.96E-08	cm/s
0 time after 1440 minutes of permeability run.		AVERAGE,k USE FOR ANALYSES	1.96E-08	cm/s
Data by F.A.R.				

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 30



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

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FIGURE 31

BOREHOLE NUMBER 85-6-B PROJECT 861-1121
 SAMPLE NUMBER 6 Horizontal Direction
 SAMPLE DEPTH 22.33 m (GLAL PROJECT 885-6H-8)
 SAMPLE TYPE Silty clay occasional silt seams

ORIGINAL: LENGTH cm	4.910	CONSOLIDATED: AREA cm ²	18.71	WET WEIGHT gm	187.7
DIAMETER cm	5.010	LENGTH cm	4.78	DRY WEIGHT gm	143.8
AREA cm ²	19.716	PRESSURE kPa	230.13	VOLUME WATER cc	43.9
VOLUME cc	96.806	HYDRAULIC GRADIENT (p/l)	20.04		

WATER CONTENT initial %	30.50	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	29.10	VOLUME SOLIDS cc	51.727	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	19.01	VOLUME VOIDS cc	45.080	CLAY FRACTION (0.002mm) %	
DRY UNIT WEIGHT kN/m ³	14.56	VOID RATIO	0.871	SILT FRACTION (0.06mm) %	
IS/FLS	92.71	SATURATION %	97.361		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure kPa	Back Pressure kPa	Test Duration min	Volume Water cc	S Value
275.6	268.7	2050	3.7	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure kPa	Head Pressure kPa	Back Pressure kPa	Effective Head Pressure kPa	Constant Ah	Effective Confining Pressure Top kPa	Base kPa
528.5	278.4	268.7	9.65	1841.403	230.1	239.8

DATE YY-MM-DD	CLOCK time	ELAPSED TIME min.	ELAPSED TIME sec.	INFLOW Vc cc	aVc cc	OUTFLOW Vc cc	aVc cc	DAILY PERMEABILITY RESULTS	
								INFLOW cm/s	OUTFLOW cm/s
86-06-13	09:30	0	0	9.50	0.0	67.10	0.0		
86-06-13	16:52	442	26520	9.60	0.10	67.40	0.30	9.79E-09	2.94E-08
86-06-14	15:27	1797	107920	10.20	0.70	68.20	1.10	1.92E-08	2.55E-08
86-06-15	11:25	2995	179700	10.70	1.20	68.90	1.60	1.81E-08	2.53E-08
86-06-16	09:01	4291	257460	11.30	1.80	69.60	2.50	2.20E-08	2.34E-08

COEFFICIENT OF PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
4291	2.59E-08		3849	2.47E-08	cm/s
	OUTFLOW, k	2.59E-08		OUTFLOW, k	2.47E-08 cm/s
	AVERAGE, k	2.59E-08		AVERAGE, k	2.47E-08 cm/s

NOTES

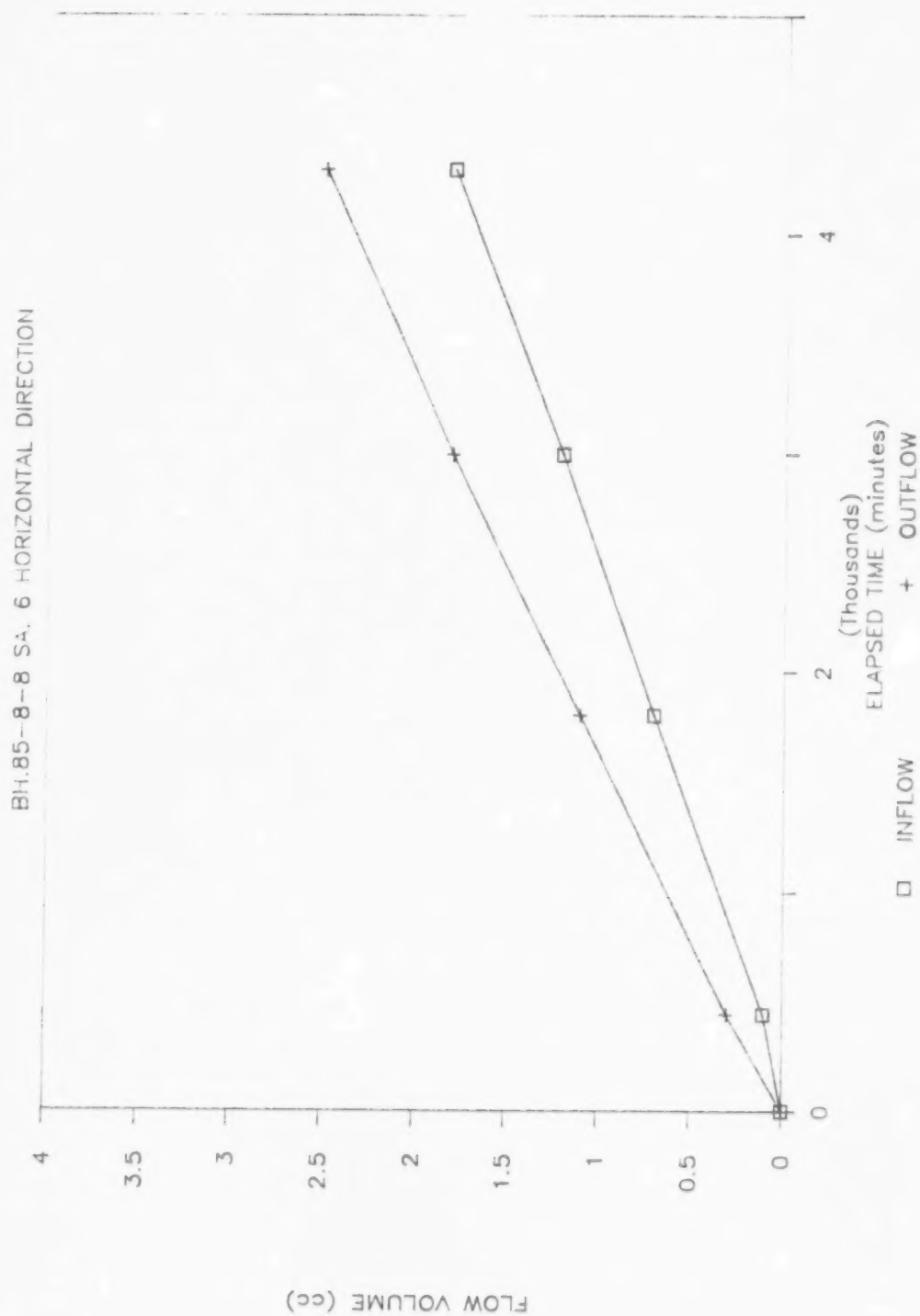
Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test.
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

PART 2		
MINUTES	INFLOW, k	
n/a	OUTFLOW, k	1/a cm/s
	AVERAGE, k	1/a cm/s
	AVERAGE, k USE FOR ANALYSES	2.47E-08 cm/s

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

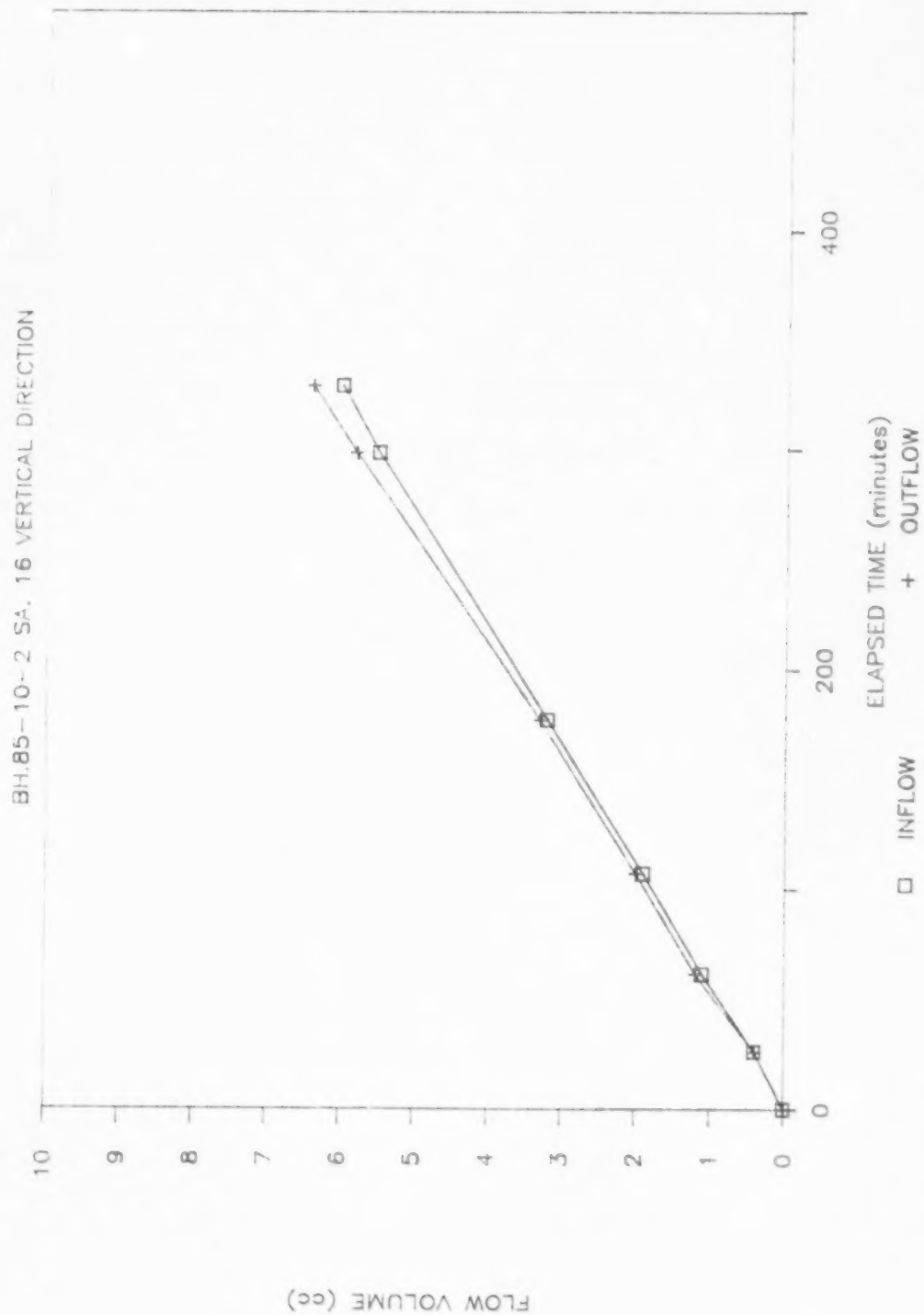
FIGURE 32



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 34



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

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FIGURE 35

BOREHOLE NUMBER 85-10-2 PROJECT 861-1121
 SAMPLE NUMBER 16 Horizontal Direction
 SAMPLE DEPTH 16.13 m (GLAL PROJECT #85-GH-9)
 SAMPLE TYPE Silt to clayey silt trace fine sand

ORIGINAL: LENGTH cm	5.210	CONSOLIDATED: AREA cm ²	19.84	WET WEIGHT gm	231.5
DIAMETER cm	5.100	LENGTH cm	5.13	DRY WEIGHT gm	195.0
AREA cm ²	20.431	PRESSURE kPa	159.85	VOLUME WATER cc	36.5
VOLUME cc	106.445	HYDRAULIC GRADIENT (p/l)	20.24		

WATER CONTENT initial %	10.70	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %
WATER CONTENT final %	16.00	VOLUME SOLIDS cc	70.144	PLASTIC INDEX %
UNIT WEIGHT kN/m ³	21.32	VOLUME VOIDS cc	36.301	CLAY FRACTION (.002mm) %
DRY UNIT WEIGHT kN/m ³	17.96	VOID RATIO	0.517	SILT FRACTION (.06mm) %
lb/ft ³	114.33	SATURATION %	100.549	

SATURATION by BACK PRESSURE (achieved)

Cell Pressure kPa	Back Pressure kPa	Test Duration min	Volume Water cc	B Value
275.6	268.7	4000	0.9	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure kPa	Head Pressure kPa	Back Pressure kPa	Effective Head Pressure kPa	Constant Ah	Effective Confining Pressure Top kPa	Effective Confining Pressure Base kPa
438.9	279.0	268.7	10.33	2092.068	159.8	170.2

DATE YY-MM-DD	CLOCK time	ELAPSED TIME min.	ELAPSED TIME sec.	INFLOW Vc cc	aVc cc	OUTFLOW Vc cc	aVc cc	DAILY PERMEABILITY RESULTS	
								INFLOW cm/s	OUTFLOW cm/s
86-06-24	10:41	0	0	76.40	0.0	56.90	0.0		
86-06-24	11:44	63	3780	78.30	1.90	55.00	1.90	1.23E-06	1.23E-06
86-06-24	12:29	108	6480	79.60	3.20	53.60	3.30	1.18E-06	1.27E-06
86-06-24	13:38	177	10620	81.60	5.20	51.60	5.30	1.18E-06	1.18E-06
86-06-24	14:35	234	14040	83.10	6.70	50.00	6.90	1.08E-06	1.15E-06

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
234	OUTFLOW, k	1.21E-06	171	OUTFLOW, k	1.15E-06 cm/s
	AVERAGE, k	1.21E-06		AVERAGE, k	1.19E-06 cm/s
					1.17E-06 cm/s
NOTES			PART 2		
			MINUTES	INFLOW, k	
			n/a	OUTFLOW, k	n/a cm/s
				AVERAGE, k	n/a cm/s
			AVERAGE, k USE FOR ANALYSES		1.17E-06 cm/s

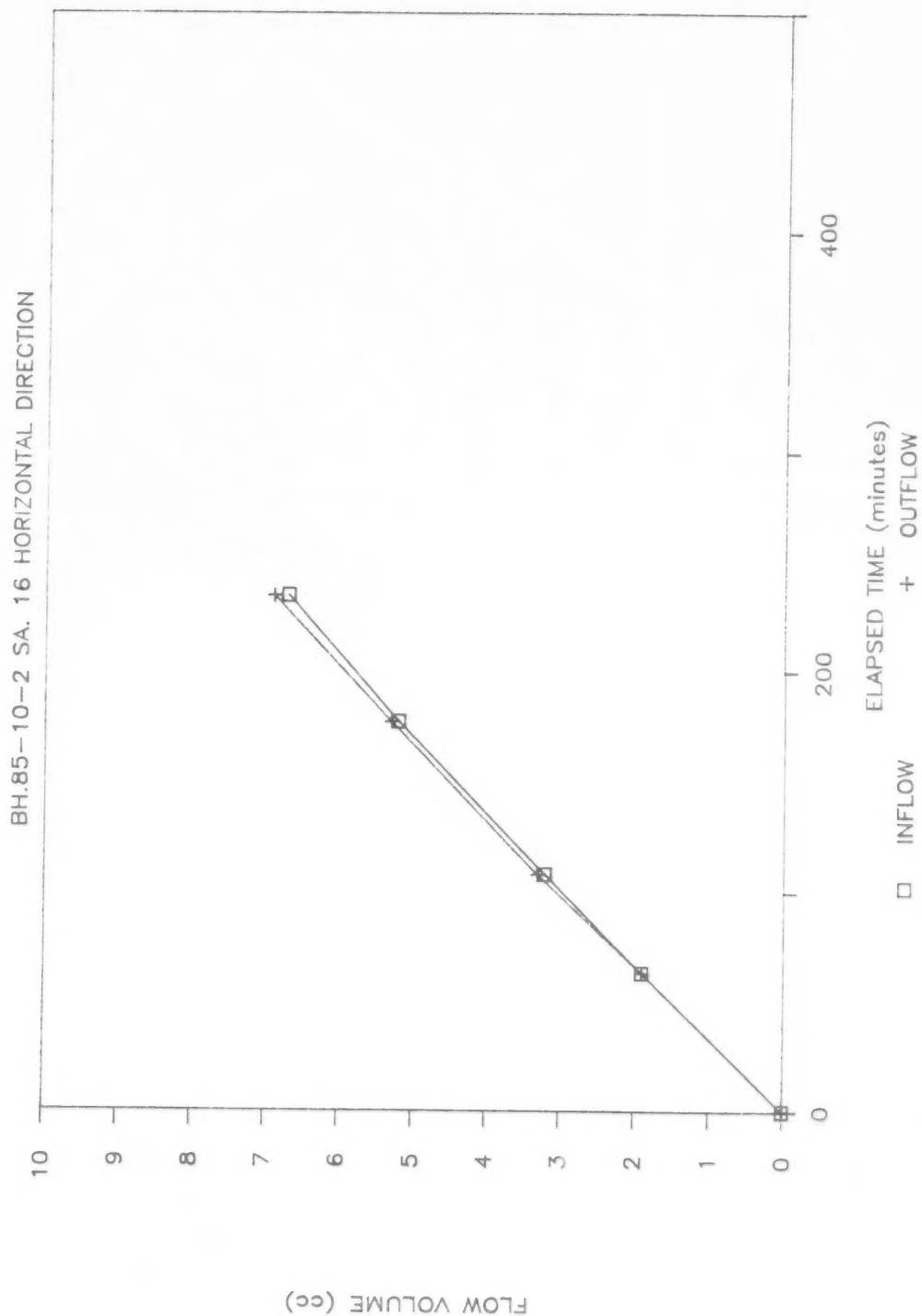
Membrane not sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 36



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 37

BOREHOLE NUMBER 85-10-2 PROJECT 861-1121
 SAMPLE NUMBER 24 Vertical Direction
 SAMPLE DEPTH 25.27 m (GLAL PROJECT #85-6H-8)
 SAMPLE TYPE Silty clay occasional silt seams

ORIGINAL: LENGTH cm	5.820	CONSOLIDATED: AREA cm ²	19.32	WET WEIGHT gm	228.7
DIAMETER cm	5.050	LENGTH cm	5.72	DRY WEIGHT gm	174.7
AREA cm ²	20.032	PRESSURE kPa	259.75	VOLUME WATER cc	54.8
VOLUME cc	116.587	HYDRAULIC GRADIENT (p/l)	19.33		

WATER CONTENT initial %	30.90	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	31.70	VOLUME SOLIDS cc	62.842	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	19.23	VOLUME VOIDS cc	53.746	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	14.69	VOID RATIO	0.855	SILT FRACTION (.06mm) %	
lb/ft ³	93.52	SATURATION %	100.529		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	θ Value
kPa	kPa	min	cc	
206.7	199.8	2520	4.7	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
470.6	210.8	199.8	11.02	2173.072	259.8	270.8

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW	OUTFLOW	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cm/s	cm/s
86-06-21	12:54	0	0	17.20	0.0		
86-06-23	08:36	2622	157320	15.90	1.30	2.17E-08	2.01E-08
86-06-23	15:43	3049	182940	15.80	1.40	1.83E-08	6.16E-09
86-06-23	16:54	3120	187200	15.70	1.50	6.18E-08	6.18E-08
86-06-24	08:36	4062	243720	15.20	2.00	2.33E-08	1.40E-08
86-06-24	12:00	4266	255960	15.10	2.10	2.15E-08	4.30E-08

COEFFICIENT OF PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
4266	OUTFLOW, k	4.01E-08	2622	OUTFLOW, k	2.17E-08 cm/s
	AVERAGE, k	4.01E-08		AVERAGE, k	2.01E-08 cm/s

NOTES

Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

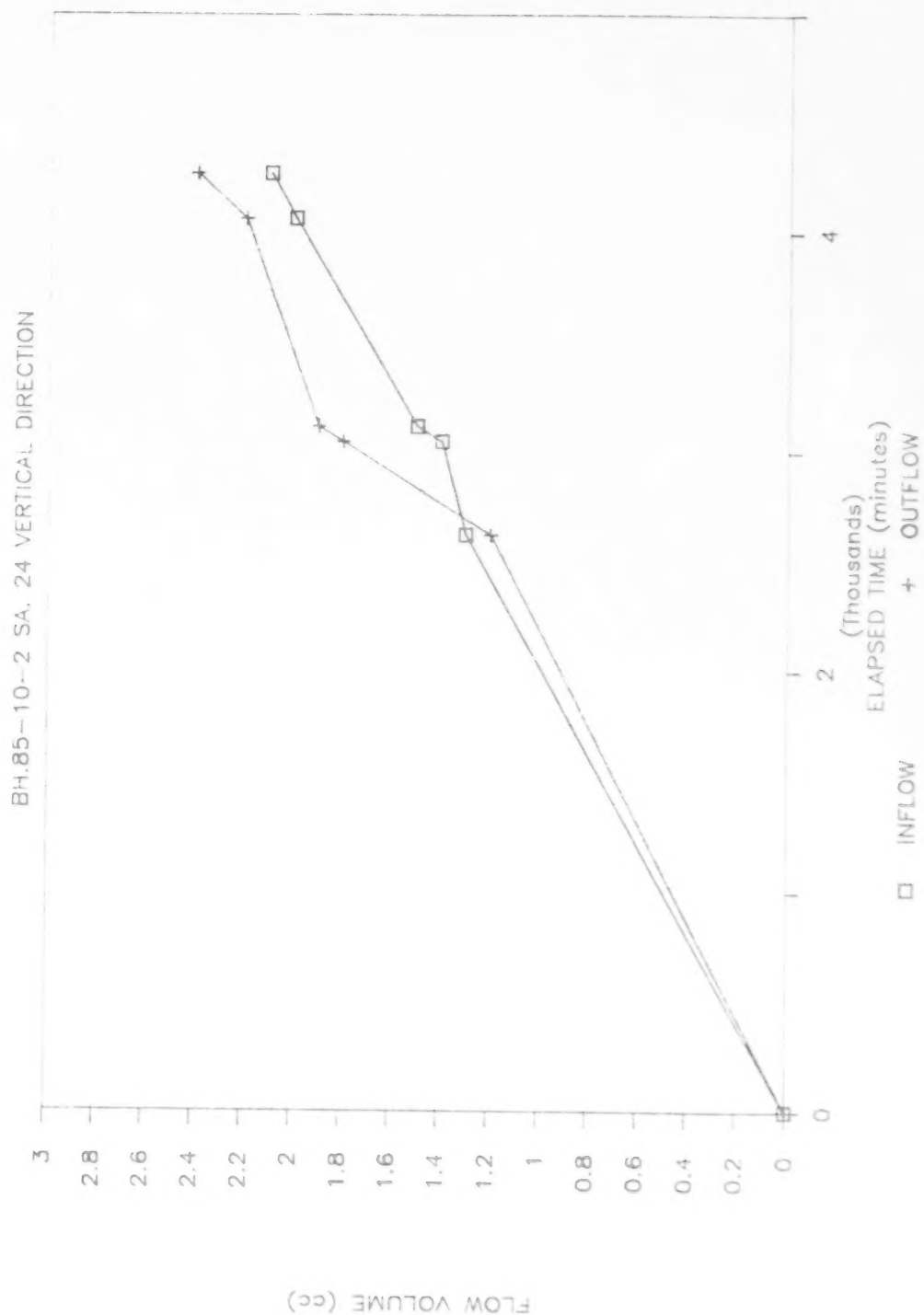
PART 2		
MINUTES	INFLOW, k	
1644	OUTFLOW, k	2.13E-08 cm/s
	AVERAGE, k	3.20E-08 cm/s
	AVERAGE, k	2.67E-08 cm/s
	AVERAGE, k USE FOR ANALYSES	2.67E-08 cm/s

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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 38



TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 39

SHEET 1 OF 2

BOREHOLE NUMBER 85-10-2 PROJECT 861-1121
 SAMPLE NUMBER 24 Horizontal Direction
 SAMPLE DEPTH 25.02 m (GLAL PROJECT 885-GH-8)
 SAMPLE TYPE Silty clay occasional silt seams

ORIGINAL: LENGTH cm	5.160	CONSOLIDATED: AREA cm ²	18.44	WET WEIGHT gm	211.9
DIAMETER cm	4.968	LENGTH cm	5.04	DRY WEIGHT gm	168.7
AREA cm ²	19.325	PRESSURE kPa	259.75	VOLUME WATER cc	43.2
VOLUME cc	99.715	HYDRAULIC GRADIENT (p/l)	19.07		

WATER CONTENT initial %	25.60	SPECIFIC GRAVITY	2.700	LIQUID LIMIT %	
WATER CONTENT final %	28.40	VOLUME SOLIDS cc	60.683	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.83	VOLUME VOIDS cc	39.031	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	16.59	VOID RATIO	0.643	SILT FRACTION (.06mm) %	
lb/ft ³	105.58	SATURATION %	110.680		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
206.7	199.8	1300	7.9	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Effective Confining Pressure	Constant Ah	Top	Base
kPa	kPa	kPa	kPa			kPa	kPa
469.2	209.5	199.8	9.65		1814.830	259.8	269.4

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW	OUTFLOW	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	Vc	aVc
		min.	sec.	cc	cc	cc	cc
86-07-01	15:30	0	0	58.20	0.0	13.40	0.0
86-07-02	08:43	1033	61900	57.40	0.80	14.00	0.60
86-07-02	12:20	1250	75000	57.30	0.90	14.30	0.90
86-07-02	16:39	1509	90540	57.10	1.10	14.40	1.00
86-07-03	09:11	2501	150060	56.60	1.60	14.90	1.50
86-07-03	16:36	2946	176760	56.40	1.80	15.20	1.80
86-07-04	09:28	3958	237480	55.00	2.40	15.80	2.40

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
3958	OUTFLOW, k	3.18E-08	2925	OUTFLOW, k	2.85E-08
	AVERAGE, k	3.18E-08		AVERAGE, k	2.69E-08
NOTES			PART 2		
			MINUTES	INFLOW, k	n/a
			n/a	OUTFLOW, k	n/a
				AVERAGE, k	n/a
			AVERAGE, k USE FOR ANALYSES	2.69E-08	cm/s

Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

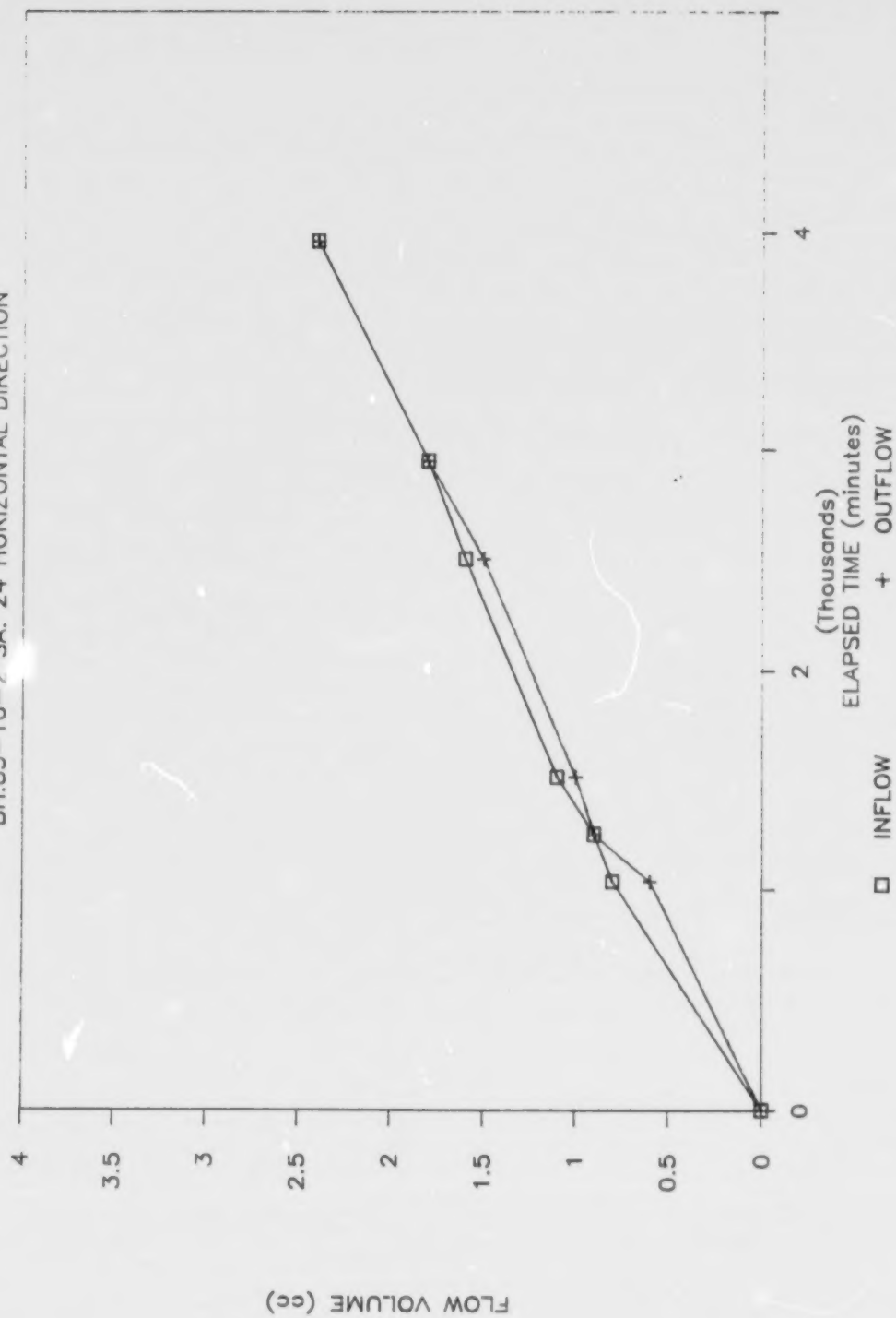
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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 40

BH.85-10-2 SA. 24 HORIZONTAL DIRECTION



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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 41

BOREHOLE NUMBER 05-12-0 PROJECT 061-1121
 SAMPLE NUMBER 1 Vertical Direction
 SAMPLE DEPTH 3.57 m 16LAL PROJECT 005-6H-0)
 SAMPLE TYPE Silty clay with clayey silt pockets

ORIGINAL: LENGTH cm	7.490	CONSOLIDATED: AREA cm ²	19.94	WET WEIGHT gm	317.2
DIAMETER cm	5.050	LENGTH cm	7.47	DRY WEIGHT gm	266.6
AREA cm ²	20.032	PRESSURE kPa	44.70	VOLUME WATER cc	50.6
VOLUME cc	150.041	HYDRAULIC GRADIENT (p/l)	19.71		

WATER CONTENT initial %	19.00	SPECIFIC GRAVITY	2.700	LIQUID LIMIT %	
WATER CONTENT final %	19.30	VOLUME SOLIDS cc	95.899	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.72	VOLUME VOIDS cc	54.142	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	17.42	VOID RATIO	0.565	SILT FRACTION (.06mm) %	
lb/ft ³	110.06	SATURATION %	93.450		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
175.7	130.9	1201	3.1	0.90

PERMEABILITY TEST CONDITIONS :

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Base
kPa	kPa	kPa	kPa		kPa	kPa
190.2	145.4	130.9	14.47	2943.686	44.8	59.3

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW trns#4	OUTFLOW trns#3	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cm/s	cm/s
06-05-14	15:37	0	0	0.0566	0.0	0.6801	0.0
06-05-14	16:50	01	4860	0.0592	0.09	0.6830	0.10
06-05-15	09:07	1050	63000	0.0878	1.09	0.7110	1.13
06-05-15	11:54	1217	73020	0.0914	1.21	0.7169	1.31
06-05-15	16:16	1479	88740	0.0972	1.41	0.7248	1.59
06-05-16	00:40	2471	140260	0.9202	2.21	0.7501	2.49

COEFFICIENT of PERMEABILITY, k, cm/s

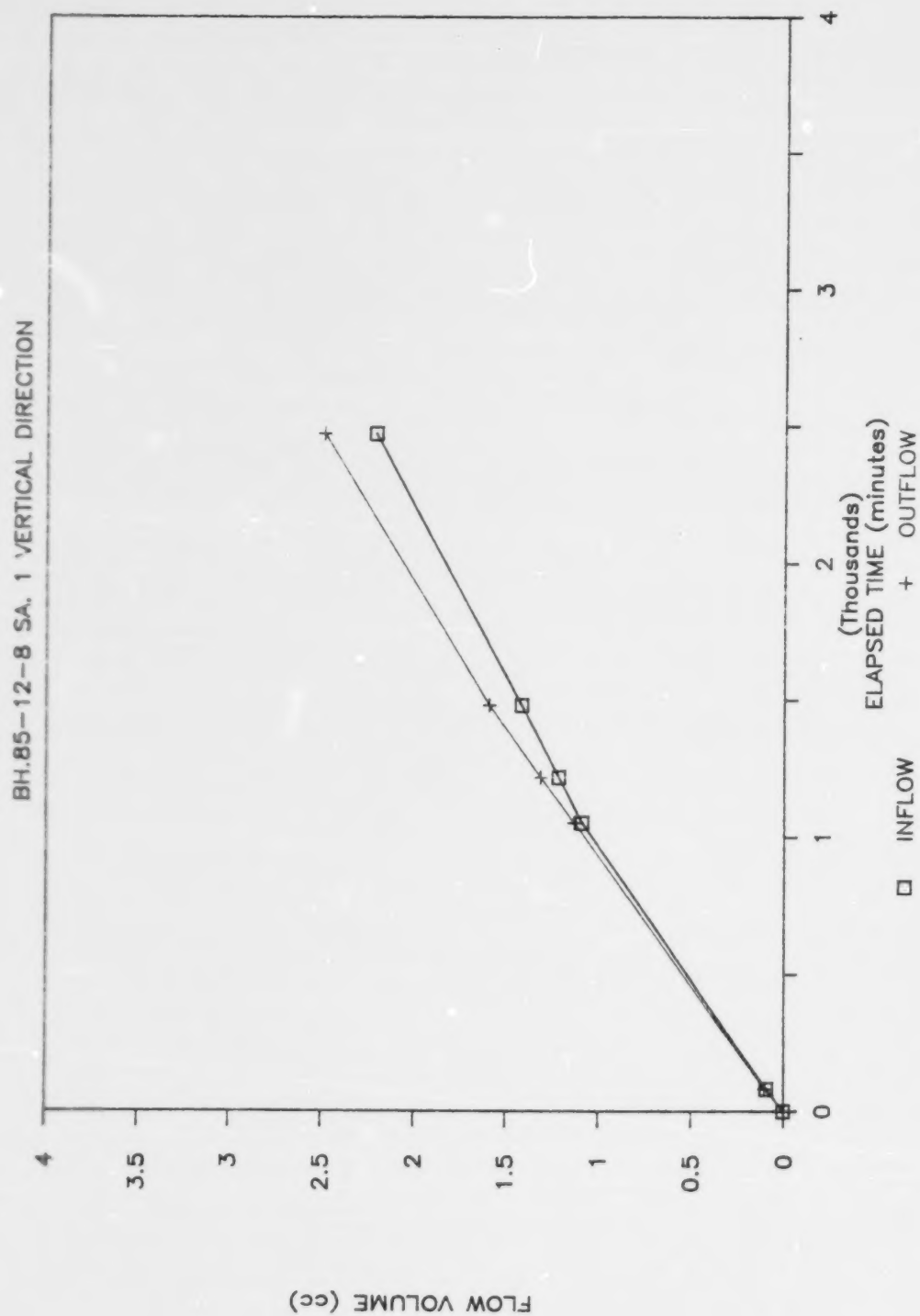
TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
2471	OUTFLOW, k	4.57E-08	1390	OUTFLOW, k	4.50E-08
	AVERAGE, k	4.57E-08		AVERAGE, k	4.25E-08
NOTES			PART 2		
			MINUTES	INFLOW, k	
			992	OUTFLOW, k	3.84E-08
				AVERAGE, k	3.63E-08
				AVERAGE, k USE FOR ANALYSES	3.63E-08

Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 42



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 43

SHEET 1 OF 2

BOREHOLE NUMBER 85-12-8 PROJECT 861-1121
 SAMPLE NUMBER 1 Horizontal Direction
 SAMPLE DEPTH 3.49 m (GLAL PROJECT 085-6H-8)
 SAMPLE TYPE Silty clay with clayey silt pockets, fissured

ORIGINAL: LENGTH cm	5.710	CONSOLIDATED: AREA cm ²	19.80	WET WEIGHT gm	240.8
DIAMETER cm	5.040	LENGTH cm	5.69	DRY WEIGHT gm	201.5
AREA cm ²	19.953	PRESSURE kPa	48.23	VOLUME WATER cc	39.3
VOLUME cc	113.931	HYDRAULIC GRADIENT (p/l)	19.70		

WATER CONTENT initial %	20.90	SPECIFIC GRAVITY	2.700	LIQUID LIMIT %	
WATER CONTENT final %	19.50	VOLUME SOLIDS cc	72.482	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.72	VOLUME VOIDS cc	41.449	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	17.14	VOID RATIO	0.572	SILT FRACTION (.06mm) %	
lb/ft ³	109.09	SATURATION %	94.814		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
175.7	130.9	1260	3.1	0.98

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
190.2	141.9	130.9	11.02	2227.061	48.2	59.3

DATE	CLOCK	ELAPSED TIME	ELAPSED TIME	INFLOW trns#1	OUTFLOW trns#2	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	min.	sec.	Vc cc	aVc cc	INFLOW cm/s	OUTFLOW cm/s
86-05-16	00:47	0	0	1.0042	0.0		
86-05-16	12:00	201	12060	1.0035	0.02	5.09E-09	2.39E-08
86-05-16	16:22	455	27300	1.0031	0.04	2.30E-09	1.50E-08
86-05-17	14:25	1770	106600	0.9836	0.71	2.15E-08	2.46E-08
86-05-19	15:09	4702	282120	0.9621	1.44	1.07E-08	1.21E-08
86-05-20	11:20	5913	354700	0.9490	1.89	1.58E-08	1.50E-08

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW

MINUTES	INFLOW, k	1.83E-08
59:3	OUTFLOW, k	1.83E-08
	AVERAGE, k	1.83E-08

NOTES

Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

PART 1

MINUTES	INFLOW, k	1.22E-08	cm/s
41:35	OUTFLOW, k	1.29E-08	cm/s
	AVERAGE, k	1.26E-08	cm/s

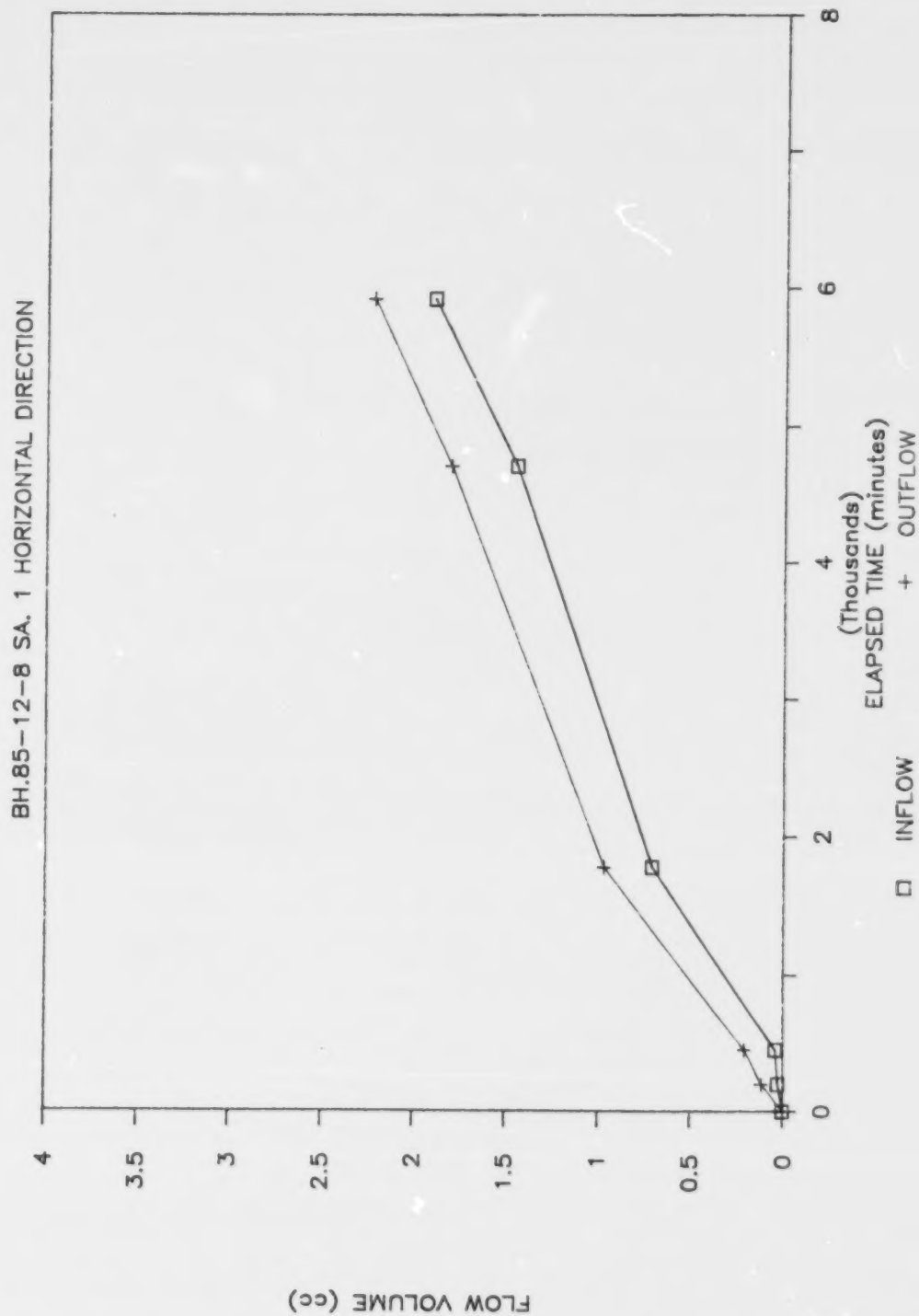
PART 2

MINUTES	INFLOW, k	1.58E-08	cm/s
12:11	OUTFLOW, k	1.50E-08	cm/s
	AVERAGE, k	1.54E-08	cm/s
	AVERAGE, k USE FOR ANALYSES	1.54E-08	cm/s

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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 44



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 45

SHEET 1 OF 2

BOREHOLE NUMBER 85-12-8 PROJECT 861-1121
 SAMPLE NUMBER 3 Vertical Direction
 SAMPLE DEPTH 11.13 m (GLAL PROJECT 865-6H-8)
 SAMPLE TYPE Silty clay with clayey silt pockets, fine gravel

ORIGINAL: LENGTH cm	6.620	CONSOLIDATED: AREA cm ²	18.77	WET WEIGHT gm	270.2
DIAMETER cm	4.950	LENGTH cm	6.54	DRY WEIGHT gm	224.9
AREA cm ²	19.247	PRESSURE kPa	110.24	VOLUME WATER cc	45.3
VOLUME cc	127.413	HYDRAULIC GRADIENT (p/l)	20.18		

WATER CONTENT initial %	20.10	SPECIFIC GRAVITY	2.700	LIQUID LIMIT %	
WATER CONTENT final %	20.50	VOLUME SOLIDS cc	80.899	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.79	VOLUME VOIDS cc	46.514	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	17.31	VOID RATIO	0.575	SILT FRACTION (.06mm) %	
lb/ft ³	110.18	SATURATION %	97.369		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
241.1	130.9	1267	0.8	0.97

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
254.2	144.0	130.9	13.09	2507.061	110.2	123.3

DATE	CLOCK	ELAPSED TIME	ELAPSED TIME	INFLOW Vc	aVc	OUTFLOW Vc	aVc	DAILY PERMEABILITY RESULTS INFLOW	OUTFLOW
YY-MM-DD	time	min.	sec.	cc	cc	cc	cc	cm/s	cm/s
86-05-14	15:35	0	0	47.20	0.0	64.50	0.0		
86-05-14	17:00	05	5100	47.30	0.10	64.70	0.10	5.11E-08	5.11E-08
86-05-15	09:15	1060	63600	48.00	0.80	63.30	1.50	3.12E-08	6.24E-08
86-05-15	11:39	1204	72240	48.10	0.90	63.10	1.70	3.02E-08	6.04E-08
86-05-15	16:37	1502	90120	48.30	1.10	62.70	2.10	2.92E-08	5.84E-08
86-05-16	08:50	2475	140500	49.20	2.00	61.50	3.30	4.02E-08	5.36E-08

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k	5.72E-08	MINUTES	INFLOW, k	3.12E-08 cm/s
2475	OUTFLOW, k	5.72E-08	975	OUTFLOW, k	6.24E-08 cm/s
	AVERAGE, k	5.72E-08		AVERAGE, k	4.68E-08 cm/s

NOTES

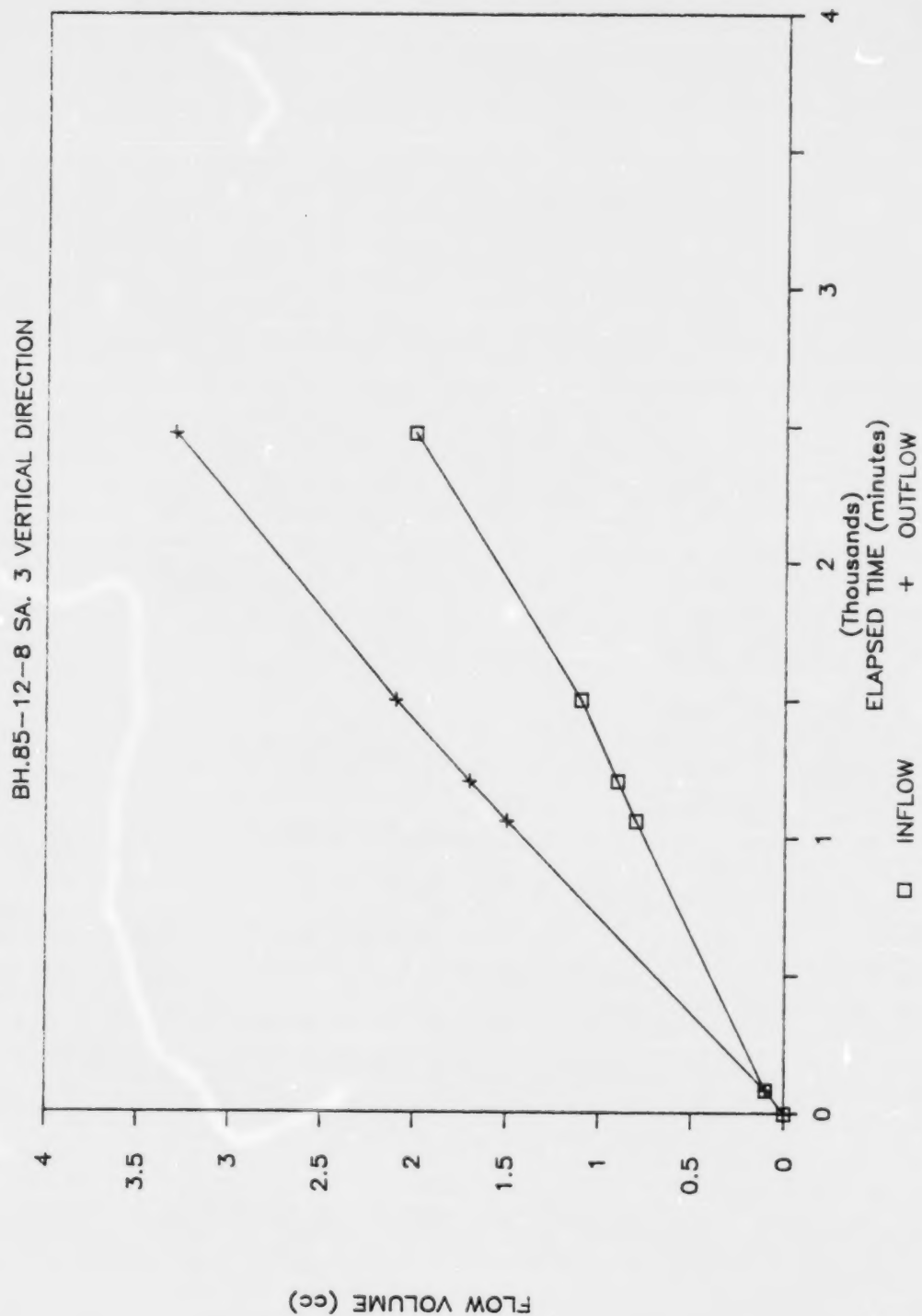
Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

PART 2		
MINUTES	INFLOW, k	3.69E-08 cm/s
1271	OUTFLOW, k	5.33E-08 cm/s
	AVERAGE, k	4.61E-08 cm/s
	AVERAGE, k USE FOR ANALYSES	4.61E-08 cm/s

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 46



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 47

BOREHOLE NUMBER 95-12-8 PROJECT 861-1121
 SAMPLE NUMBER 3 Horizontal Direction
 SAMPLE DEPTH 10.96 m (GLAL PROJECT 085-6H-8)
 SAMPLE TYPE Silty clay with clayey silt pockets, fine gravel

ORIGINAL: LENGTH cm	5.970	CONSOLIDATED: AREA cm ²	17.34	WET WEIGHT gm	217.8
DIAMETER cm	4.720	LENGTH cm	5.94	DRY WEIGHT gm	179.8
AREA cm ²	17.500	PRESSURE kPa	110.24	VOLUME WATER cc	38.0
VOLUME cc	104.473	HYDRAULIC GRADIENT (p/l)	20.02		

WATER CONTENT initial %	21.10	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	20.90	VOLUME SOLIDS cc	64.676	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.44	VOLUME VOIDS cc	39.797	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	16.88	VOID RATIO	0.615	SILT FRACTION (.06mm) %	
lb/ft ³	107.43	SATURATION %	95.510		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
241.1	130.9	1274	1.2	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure	Base
kPa	kPa	kPa	kPa		Top kPa	kPa
252.9	142.6	130.9	11.71	2072.264	110.2	121.9

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW	OUTFLOW	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	min.	sec.	Vc cc	aVc cc	INFLOW cm/s	OUTFLOW cm/s
86-05-14	15:36	0	0	0.00	0.0		
86-05-14	16:58	82	4920	0.10	0.10	5.93E-08	0.00E+00
86-05-15	09:09	1053	63100	0.40	0.40	1.40E-08	1.97E-08
86-05-15	11:34	1190	71800	0.40	0.40	0.00E+00	0.00E+00
86-05-15	16:15	1479	88740	0.50	0.50	1.70E-08	1.70E-08
86-05-16	09:43	2467	148020	0.80	1.00	2.42E-08	2.42E-08

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
2467	OUTFLOW, k	1.22E-08	971	OUTFLOW, k	1.97E-08 cm/s
	AVERAGE, k	1.22E-08		AVERAGE, k	1.72E-08 cm/s
NOTES			PART 2		
			MINUTES	INFLOW, k	
			1269	OUTFLOW, k	2.26E-08 cm/s
				AVERAGE, k	2.26E-08 cm/s
				AVERAGE, k USE FOR ANALYSES	2.26E-08 cm/s

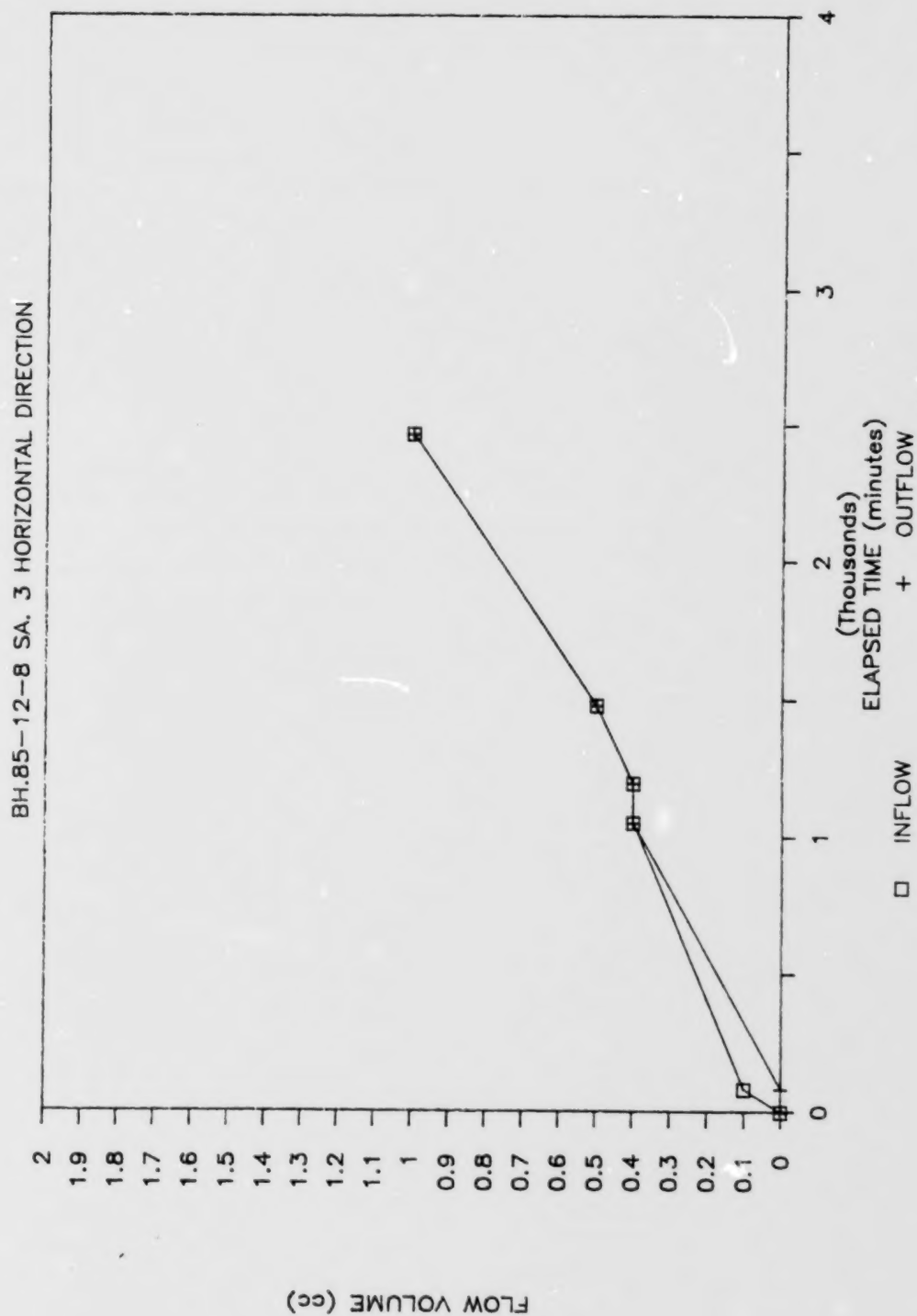
Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 48



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 49

SHEET 1 OF 2

BOREHOLE NUMBER 85-12-8 PROJECT 861-1121
 SAMPLE NUMBER 5 Vertical Direction
 SAMPLE DEPTH 21.72 m (61AL PROJECT 885-6H-8)
 SAMPLE TYPE Silty clay with gravel, till like

ORIGINAL: LENGTH cm	6.520	CONSOLIDATED: AREA cm ²	19.20	WET WEIGHT gm	269.8
DIAMETER cm	5.000	LENGTH cm	6.45	DRY WEIGHT gm	221.4
AREA cm ²	19.637	PRESSURE kPa	230.13	VOLUME WATER cc	48.4
VOLUME cc	120.036	HYDRAULIC GRADIENT (p/l)	19.42		

WATER CONTENT initial %	21.90	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	20.90	VOLUME SOLIDS cc	79.640	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.66	VOLUME VOIDS cc	40.396	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	16.95	VOID RATIO	0.600	SILT FRACTION (.06mm) %	
lb/ft ³	107.87	SATURATION %	100.000		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
275.6	268.7	5640	0.3	0.97

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
511.2	281.1	268.7	12.41	2431.481	270.1	242.5

DATE	CLOCK	ELAPSED TIME	ELAPSED TIME	INFLOW trns#3	OUTFLOW trns#4	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	min.	sec.	Vc cc	aVc cc	INFLOW cm/s	OUTFLOW cm/s
86-05-21	15:01	0	0	0.6936	0.0	1.1307	0.0
86-05-22	08:47	1066	63960	0.7019	0.30	1.1178	0.45
86-05-22	13:52	1371	82260	0.7075	0.49	1.1142	0.57
86-05-22	16:50	1549	92940	0.7104	0.60	1.1118	0.66
86-05-23	09:15	2534	152040	0.7215	0.99	1.1040	0.93
86-05-23	16:45	2984	179040	0.7356	1.50	1.0939	1.28
86-05-26	08:45	6824	409440	0.7749	2.90	1.0503	2.80

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k	2.03E-08	MINUTES	INFLOW, k	2.77E-08 cm/s
6824	OUTFLOW, k	2.03E-08	483	OUTFLOW, k	1.91E-08 cm/s
	AVERAGE, k	2.03E-08		AVERAGE, k	2.34E-08 cm/s

NOTES

Membrane sealed onto sample with vacuum grease.
 Consolidation prior to start of permeability test.
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

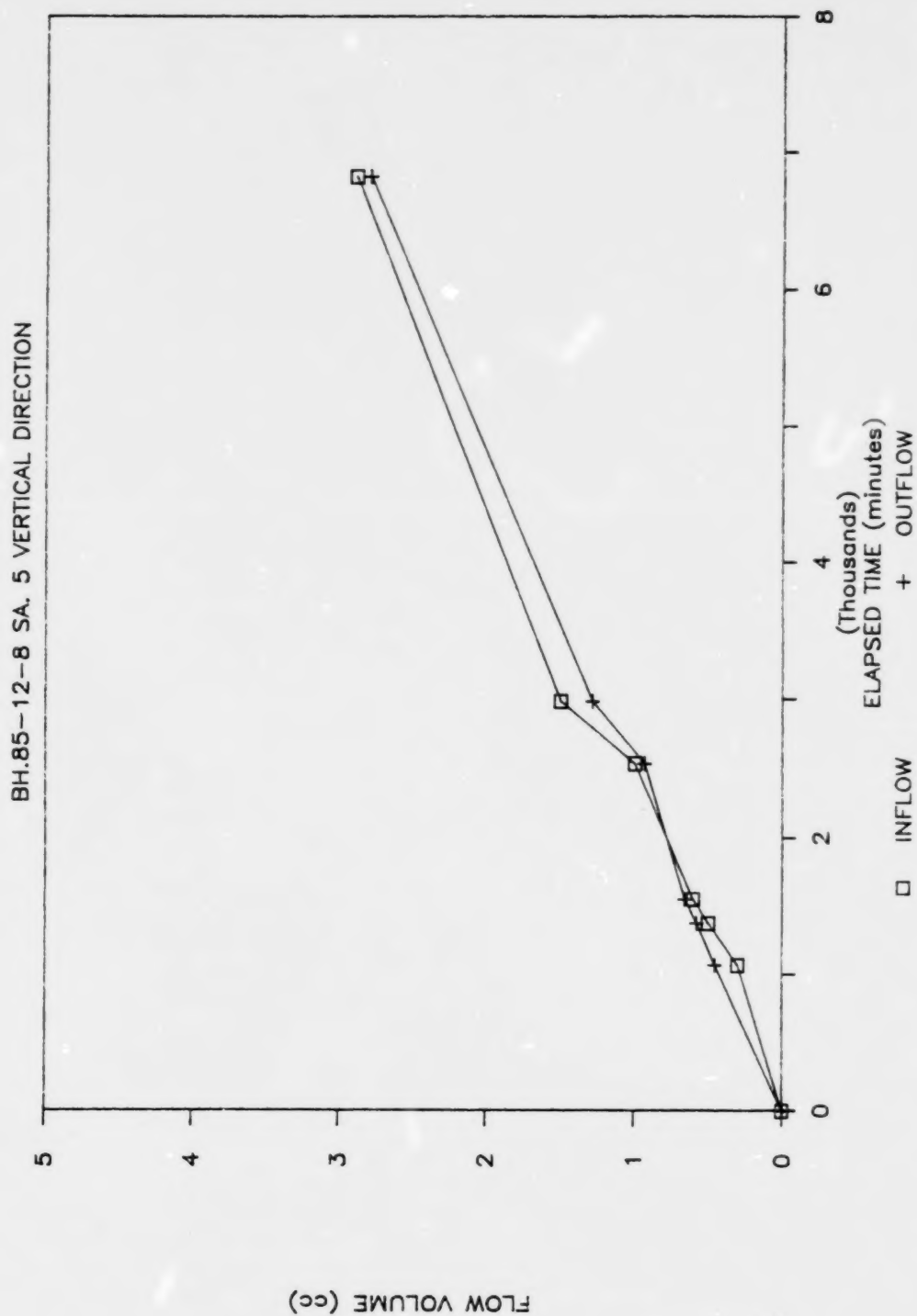
PART 2		
MINUTES	INFLOW, k	1.61E-08 cm/s
3840	OUTFLOW, k	1.75E-08 cm/s
	AVERAGE, k	1.68E-08 cm/s
	AVERAGE, k USE FOR ANALYSES	1.68E-08 cm/s

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 50



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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

FIGURE 51

SHEET 1 OF 2

BOREHOLE NUMBER 85-12-B PROJECT 861-1121
 SAMPLE NUMBER 5 Horizontal Direction
 SAMPLE DEPTH 21.69 m (GLAL PROJECT #85-6H-B)
 SAMPLE TYPE Silty clay with fine gravel, till like

ORIGINAL: LENGTH cm	5.290	CONSOLIDATED: AREA cm ²	17.32	WET WEIGHT gm	216.9
DIAMETER cm	4.950	LENGTH cm	5.03	DRY WEIGHT gm	177.7
AREA cm ²	19.247	PRESSURE kPa	230.13	VOLUME WATER cc	39.2
VOLUME cc	101.815	HYDRAULIC GRADIENT (p/l)	18.60		

WATER CONTENT initial %	22.10	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	21.90	VOLUME SOLIDS cc	63.921	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.80	VOLUME VOIDS cc	37.894	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	17.10	VOID RATIO	0.593	SILT FRACTION (.06mm) %	
lb/ft ³	100.07	SATURATION %	103.446		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
567.7	337.6	240	1.9	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Effective Confining Pressure	Constant Ah	Top kPa	Base kPa
kPa	kPa	kPa	kPa				
577.4	347.3	337.6	9.65		1704.602	230.1	239.8

DATE	CLOCK	ELAPSED TIME	ELAPSED TIME	INFLOW trns#1	OUTFLOW trns#2	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	min.	sec.	Vc cc	aVc cc	INFLOW cm/s	OUTFLOW cm/s
86-05-22	08:47	0	0	1.2380	0.0	0.5924	0.0
86-05-22	13:52	305	18300	1.2319	0.21	0.5805	0.43
86-05-22	16:49	402	28920	1.2282	0.34	0.5811	0.41
86-05-23	09:16	1469	88140	1.2056	1.11	0.5620	1.10
86-05-23	16:44	1917	115020	1.1973	1.40	0.5533	1.42
86-05-26	08:43	5756	345360	1.1236	3.92	0.4890	3.76

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
5756	OUTFLOW, k	3.26E-08	5274	OUTFLOW, k	3.35E-08 cm/s
	AVERAGE, k	3.26E-08		AVERAGE, k	3.12E-08 cm/s
					3.23E-08 cm/s

NOTES

Membrane sealed onto sample with vacuum grease.
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

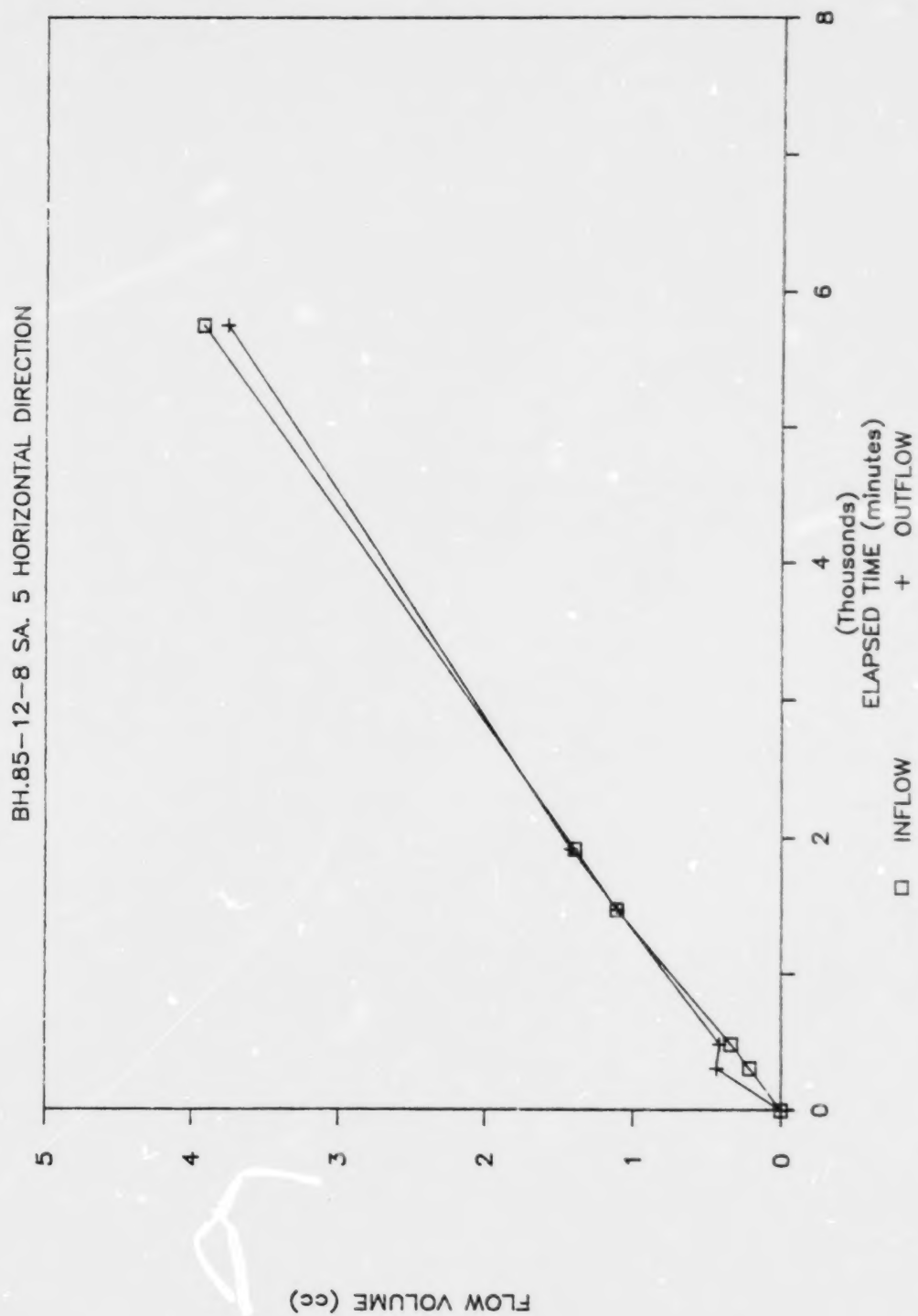
PART 2

MINUTES	INFLOW, k	
n/a	OUTFLOW, k	n/a cm/s
	AVERAGE, k	n/a cm/s
	AVERAGE, k USE FOR ANALYSES	3.23E-08 cm/s

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 52



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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 53

BOREHOLE NUMBER 85-12-22 PROJECT 861-1121
 SAMPLE NUMBER 2 Vertical Direction
 SAMPLE DEPTH 15.33 m (SLAL PROJECT 885-6H-8)
 SAMPLE TYPE Silty clay with gravel, till like

ORIGINAL: LENGTH cm	6.480	CONSOLIDATED: AREA cm ²	19.27	WET WEIGHT gm	262.8
DIAMETER cm	5.000	LENGTH cm	6.34	DRY WEIGHT gm	216.6
AREA cm ²	19.637	PRESSURE kPa	159.85	VOLUME WATER cc	46.2
VOLUME cc	125.680	HYDRAULIC GRADIENT (p/l)	19.79		

WATER CONTENT initial %	21.30	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %
WATER CONTENT final %	22.60	VOLUME SOLIDS cc	77.914	PLASTIC INDEX %
UNIT WEIGHT kN/m ³	20.50	VOLUME VOIDS cc	47.766	CLAY FRACTION (.002mm) %
DRY UNIT WEIGHT kN/m ³	16.90	VOID RATIO	0.613	SILT FRACTION (.06mm) %
lb/ft ³	107.57	SATURATION %	96.721	

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
275.6	268.7	5415	4.6	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Effective Confining Pressure
kPa	kPa	kPa	kPa	Constant Ah Top Base
441.0	281.1	268.7	12.41	2440.345 159.8 172.3

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW	OUTFLOW	DAILY PERMEABILITY RESULTS			
YY-MM-DD	time	TIME	TIME	Vc	aVc	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cc	cc	cm/s	cm/s
86-05-21	16:15	0	0	4.60	0.0	77.00	0.0		
86-05-22	08:45	990	59400	5.20	0.60	76.20	0.80	2.62E-08	3.50E-08
86-05-22	13:53	1290	77800	5.40	0.80	76.00	1.00	2.81E-08	2.81E-08
86-05-22	16:45	1470	88200	5.50	0.90	75.00	1.20	2.52E-08	5.03E-08
86-05-23	09:11	2456	147360	6.00	1.40	75.00	2.00	2.20E-08	3.51E-08
86-05-23	16:35	2900	174000	6.30	1.70	74.60	2.40	2.93E-08	3.90E-08
86-05-26	08:41	6746	404760	8.50	3.90	72.20	4.80	2.48E-08	2.70E-08

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
6746	OUTFLOW, k	3.58E-08	1466	OUTFLOW, k	2.36E-08 cm/s
	AVERAGE, k	3.58E-08		AVERAGE, k	3.54E-08 cm/s
					2.95E-08 cm/s

NOTES

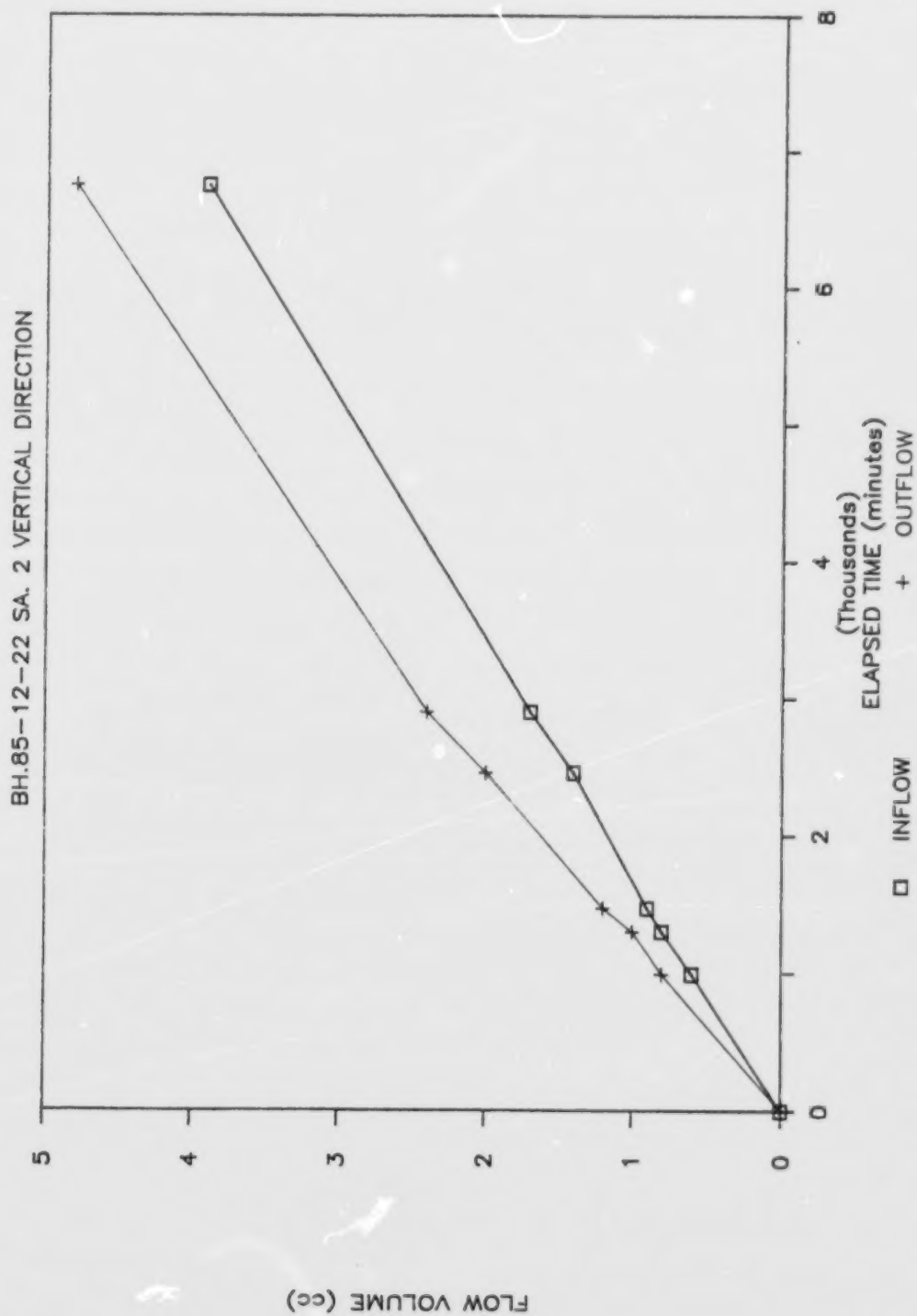
Membrane sealed onto sample with vacuum grease,
 Consolidation prior to start of permeability test,
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

PART 2		
MINUTES	INFLOW, k	
4290	OUTFLOW, k	2.52E-08 cm/s
	AVERAGE, k	2.83E-08 cm/s
		2.67E-08 cm/s
	AVERAGE, k USE FOR ANALYSES	2.67E-08 cm/s

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 54



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 55

BOREHOLE NUMBER 85-12-22 PROJECT 861-1121
 SAMPLE NUMBER 2 Horizontal Direction
 SAMPLE DEPTH 15.28 m (GLAL PROJECT 885-6H-8)
 SAMPLE TYPE Silty clay with gravel, till like

ORIGINAL: LENGTH cm	6.270	CONSOLIDATED: AREA cm ²	20.00	WET WEIGHT gm	272.2
DIAMETER cm	5.100	LENGTH cm	6.22	DRY WEIGHT gm	232.0
AREA cm ²	20.431	PRESSURE kPa	159.85	VOLUME WATER cc	40.2
VOLUME cc	120.181	HYDRAULIC GRADIENT (p/l)	20.20		

WATER CONTENT initial %	17.30	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	16.70	VOLUME SOLIDS cc	83.453	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	20.83	VOLUME VOIDS cc	44.648	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	17.76	VOID RATIO	0.535	SILT FRACTION (.075mm) %	
lb/ft ³	113.04	SATURATION %	98.037		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
275.6	268.7	5634	0.6	0.97

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure Top	Effective Confining Pressure Base
kPa	kPa	kPa	kPa		kPa	kPa
441.0	281.1	268.7	12.41	2542.923	159.8	172.3

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW		OUTFLOW		DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cc	cc	cm/s	cm/s
86-05-21	16:17	0	0	59.10	0.0	58.00	0.0		
86-05-22	00:45	900	59200	60.00	0.90	57.00	1.00	3.71E-00	4.13E-00
86-05-22	13:54	1297	77820	60.20	1.10	57.60	1.20	2.64E-00	2.64E-00
86-05-22	16:47	1470	88200	60.40	1.30	57.40	1.40	4.71E-00	4.71E-00
86-05-23	09:18	2461	147660	61.30	2.20	56.40	2.40	3.70E-00	4.11E-00
86-05-23	16:37	2900	174000	61.60	2.50	56.00	2.80	2.79E-00	3.71E-00
86-05-26	00:45	6748	404800	65.00	5.90	52.20	6.60	3.60E-00	4.03E-00

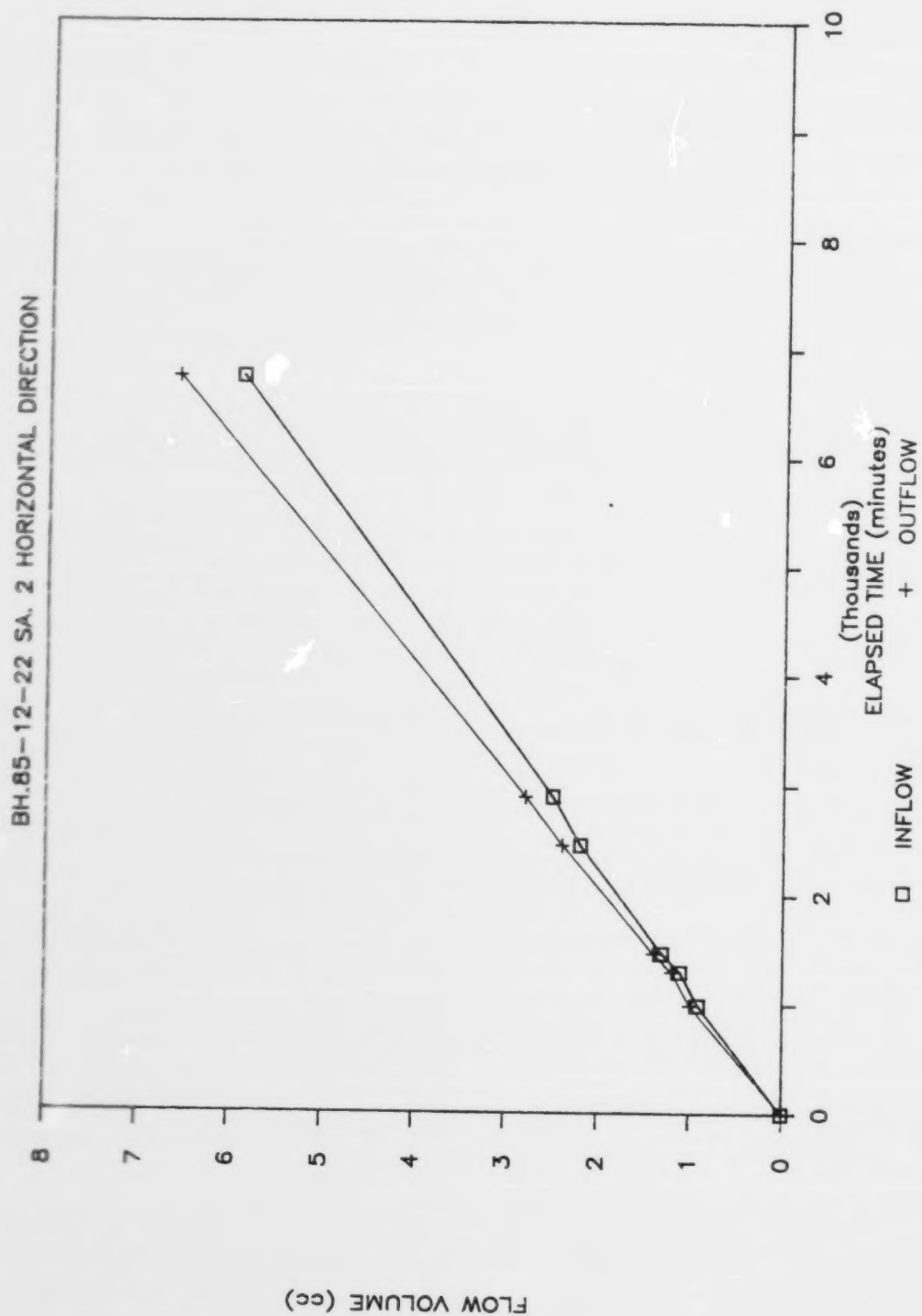
COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW				PART 1			
MINUTES	INFLOW, k			MINUTES	INFLOW, k		
6740	OUTFLOW, k	3.89E-00		5760	OUTFLOW, k	3.96E-00	cm/s
	AVERAGE, k	3.89E-00			AVERAGE, k	3.75E-00	cm/s
NOTES				PART 2			
				MINUTES	INFLOW, k	n/a	cm/s
Membrane sealed onto sample with vacuum grease.				n/a	OUTFLOW, k	n/a	cm/s
Consolidation prior to start of permeability test.					AVERAGE, k	n/a	cm/s
0 time after 1440 minutes of permeability run.				AVERAGE, k USE FOR ANALYSES 3.75E-00 cm/s			
Data by F.A.R.							

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 56



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TRIAxIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 1 OF 2

FIGURE 57

BOREHOLE NUMBER 85-12-22 PROJECT 861-1121
 SAMPLE NUMBER 4 Vertical Direction
 SAMPLE DEPTH 28.6 (GLAL PROJECT 085-6H-8)
 SAMPLE TYPE silty clay to clayey silt with fine gravel

ORIGINAL: LENGTH cm	6.450	CONSOLIDATED: AREA cm ²	19.18	WET WEIGHT gm	257.6
DIAMETER cm	5.010	LENGTH cm	6.36	DRY WEIGHT gm	202.6
AREA cm ²	19.716	PRESSURE kPa	319.70	VOLUME WATER cc	55.0
VOLUME cc	127.169	HYDRAULIC GRADIENT (p/l)	19.63		

WATER CONTENT initial %	27.10	SPECIFIC GRAVITY	2.780	LIQUID LIMIT %	
WATER CONTENT final %	25.40	VOLUME SOLIDS cc	72.078	PLASTIC INDEX %	
UNIT WEIGHT kN/m ³	19.95	VOLUME VOIDS cc	54.291	CLAY FRACTION (.002mm) %	
DRY UNIT WEIGHT kN/m ³	15.62	VOID RATIO	0.745	SILT FRACTION (.06mm) %	
lb/ft ³	99.44	SATURATION %	101.250		

SATURATION by BACK PRESSURE (achieved)

Cell Pressure	Back Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
206.7	199.8	1340	1.5	0.96

PERMEABILITY TEST CONDITIONS

Cell Pressure	Head Pressure	Back Pressure	Effective Head Pressure	Constant Ah	Effective Confining Pressure	Base
kPa	kPa	kPa	kPa		Top kPa	kPa
531.9	212.2	199.8	12.41	2428.940	319.7	332.1

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW trns#4	OUTFLOW trns#3	DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cm/s	cm/s
86-05-29	08:40	0	0	1.0710	0.0	0.6339	0.0
86-05-29	16:43	403	26900	1.0750	0.14	0.6378	0.14
86-05-30	08:33	1433	85980	1.0836	0.44	0.6400	0.22
86-05-30	14:45	1805	100300	1.0864	0.54	0.6426	0.31
86-05-31	14:25	3225	193500	1.0974	0.92	0.6515	0.63
86-06-02	09:03	5783	346980	1.1189	1.67	0.6732	1.40

COEFFICIENT of PERMEABILITY, k, cm/s

TOTAL FLOW			PART 1		
MINUTES	INFLOW, k		MINUTES	INFLOW, k	
5783	OUTFLOW, k	1.25E-08	1322	OUTFLOW, k	1.31E-08 cm/s
	AVERAGE, k	9.99E-09		AVERAGE, k	5.64E-09 cm/s
		1.12E-08			9.37E-09 cm/s

NOTES

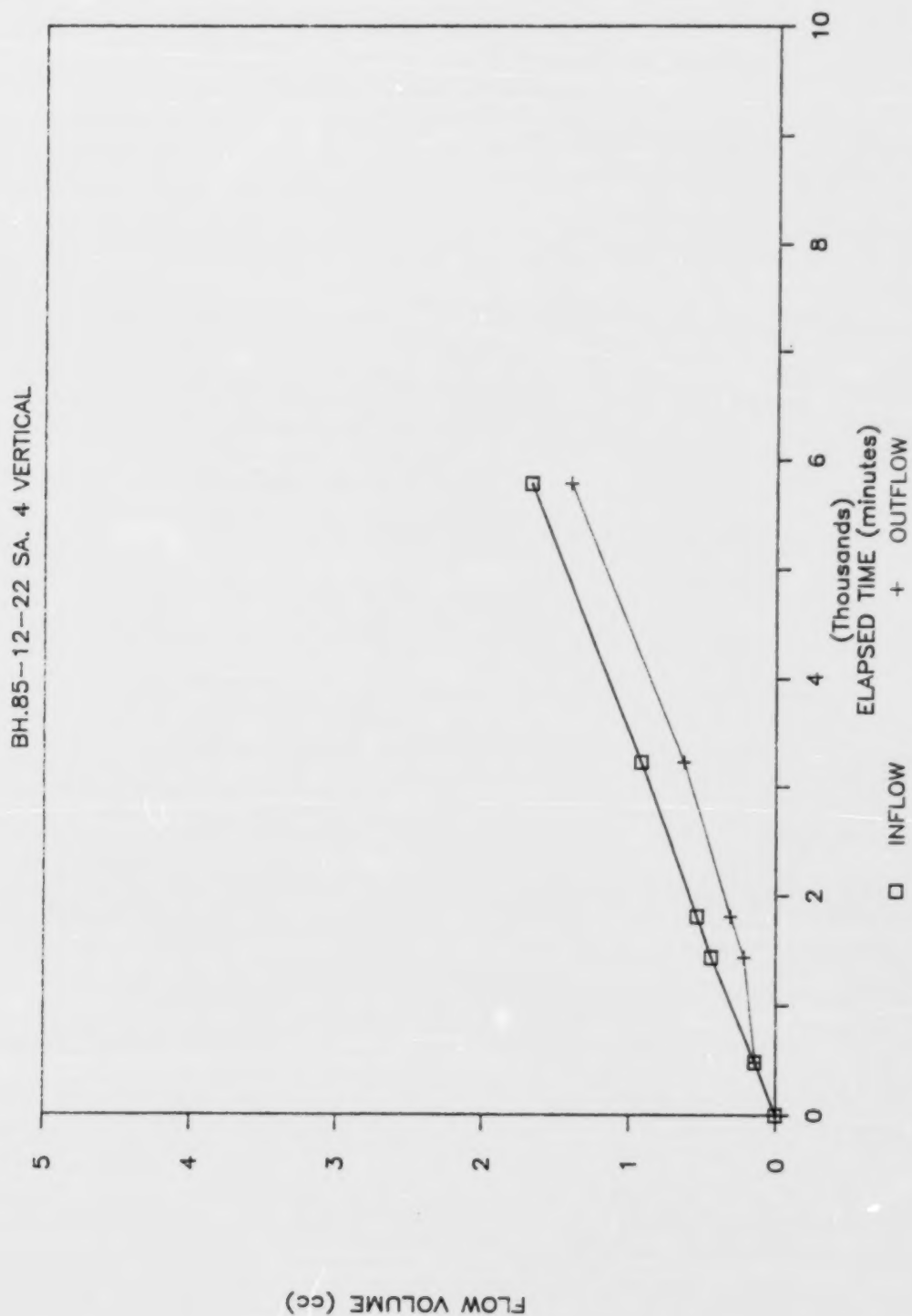
Membrane sealed onto sample with vacuum grease.
 Consolidation prior to start of permeability test.
 0 time after 1440 minutes of permeability run.
 Data by F.A.R.

PART 2		
MINUTES	INFLOW, k	
3978	OUTFLOW, k	1.24E-08 cm/s
	AVERAGE, k	1.20E-08 cm/s
		1.22E-08 cm/s
	AVERAGE, k USE FOR ANALYSES	1.22E-08 cm/s

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST
SHEET 2 OF 2

FIGURE 58



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SHEET 1 OF 2

FIGURE 59

PROJECT 861-1121

(6LAL PROJECT 065-6H-8)

(6LAL PROJECT 065-6H-8)

(6LAL PROJECT 065-6H-8)

NET WEIGHT gm	231.5
DRY WEIGHT gm	184.4
VOLUME WATER cc	47.1

LIQUID LIMIT %
PLASTIC INDEX %
CLAY FRACTION (.002mm) %
SILT FRACTION (.06mm) %

Cell Pressure	Pack Pressure	Test Duration	Volume Water	B Value
kPa	kPa	min	cc	
206.7	199.8	1339	1.1	0.98

Cell Pressure kPa	Head Pressure kPa	Back Pressure kPa	Effective Head Pressure kPa	Constant Ah	Effective Confining Pressure kPa	Base kPa
531.2	211.5	199.8	11.72	2241.487	319.7	231.4

DATE	CLOCK	ELAPSED	ELAPSED	INFLOW trns#4		OUTFLOW trns#3		DAILY PERMEABILITY RESULTS	
YY-MM-DD	time	TIME	TIME	Vc	aVc	Vc	aVc	INFLOW	OUTFLOW
		min.	sec.	cc	cc	cc	cc	cm/s	cm/s
86-05-29	00:42	0	0	0.7674	0.0	0.6090	0.0		
86-05-29	16:41	479	20740	0.7620	0.10	0.5939	0.55	1.67E-00	4.96E-00
86-05-30	00:40	1430	86200	0.7457	0.74	0.5700	1.39	2.52E-00	3.79E-00
86-05-30	14:42	1800	100000	0.7420	0.07	0.5600	1.75	1.52E-00	4.35E-00
86-05-31	14:26	3224	193440	0.7214	1.50	0.5302	2.06	2.15E-00	3.30E-00
86-06-02	09:02	5700	346000	0.6001	2.72	0.4707	4.74	1.93E-00	3.17E-00

Membrane sealed onto sample with vacuum grease,
Consolidation prior to start of permeability test,
0 time after 1440 minutes of permeability run.
Data by F.A.R.

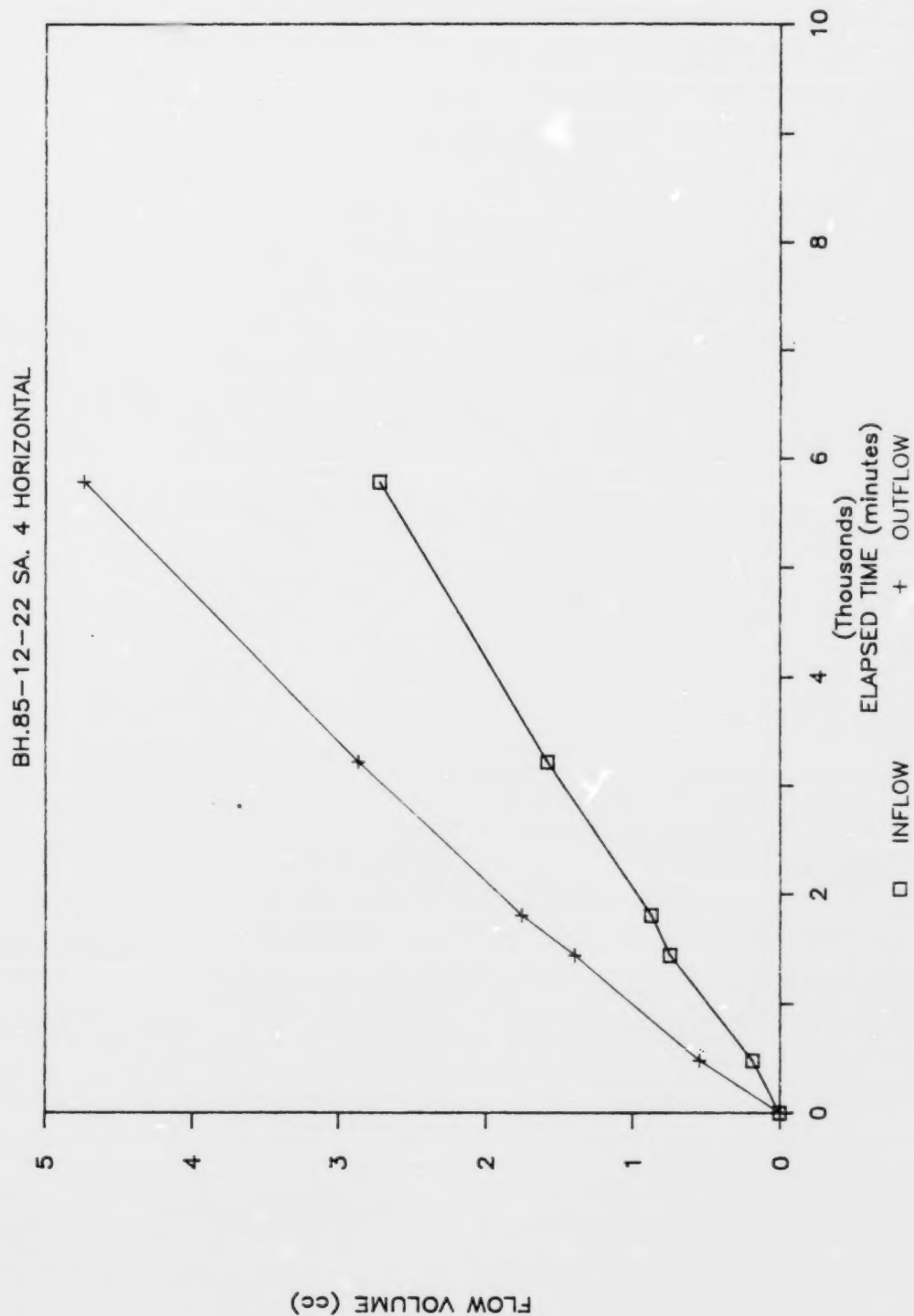
AVERAGE. USE FOR ANALYSES

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TRIAXIAL PERMEABILITY (CONSTANT HEAD) TEST

SHEET 2 OF 2

FIGURE 60



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H-1

APPENDIX H

GROUND WATER USE INFORMATION

APPENDIX H
GROUND WATER USE INFORMATION
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H1 SUMMARY OF WATER WELL DATA

H1.1 EXPLANATION OF WATER WELL DATA

Copies of original Water Well Records obtained from the Ontario Ministry of the Environment (MOE) was used for the following data summary and are on file.

Measurements, dimensions, and quantities on the Water Well Records are in Imperial units but are presented in metric units in the summary.

Water well locations were plotted on 1:10,000 scale maps for this project and elevations were re-estimated based on the more accurate contours on these maps. Well elevations are above sea level (ASL) and are estimated to the nearest metre. Well locations were checked in the field during the Water Use Survey and are shown on Figure 5-1 (in map pocket). Well number 2729 could not be located and is not shown on Figure 5-1.

Wells are arranged in numerical order on Table H1-1 according to the assigned well number.

TABLE H-1. SUMMARY OF WATER WELL DATA

Sheet 1 of 6

WELL NAME & LOCATION No.	GROUND ELEV. (m ASL)	DATE DRILLED MM YY	WELL DIAM. (mm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
430 Blish, S. Con. 2, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.)	180	May 1964	159	34.4	Fresh	33.8	4.6	9.1	0.8	Stock	0.0	33.8	Blue Clay 34.4 Grey Shale
431 Gracey, C. Con. 2, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	177	Aug 1958	127	36.3	Fresh	36.3	0.6	0.6	1.3	Stock and Domestic	0.0	36.3	Clay 36.6 Shale
446 Besser, C., Con. 3, Lot 19, West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Sep 1962	159	35.1	Fresh	34.1	9.1	12.2	0.8	Stock and Domestic	0.0	34.1	Blue Clay 34.1 35.4 Grey Limestone
447 Veendermeulen, J., Con. 3, Lot 20 West Lincoln Twp. (Formerly Gainsborough Twp.)	183	Dec 1960	159	37.2	Fresh	36.6	7.6	13.7	0.8	Stock and Domestic	0.0	36.6	Clay 36.6 37.2 Limestone
448 Bordeny, A., Con. 3, Lot 20, West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Dec 1967	159	33.8	Fresh	33.8	9.1	10.7	1.2	Stock	0.0	29.0	Clay 29.0 32.9 Clay, Gravel 32.9 33.8 Gravel

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TABLE H1-1, SUMMARY OF WATER WELL DATA

Sheet 2 of 6

WELL OWNER NAME WELL & LOCATION No.	GROUND ELEVATION (± ASL)	DATE DRILLED MM YR	WELL DIAM (mm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
466 Sarantakos, D., Con. 4, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Sep 1964	159	30.2	Fresh	29.3	9.1	9.8	1.2	Stock	0.0 29.0	29.0 31.4	Blue Clay Limestone
467 Skladas, J., Con. 4, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	187	Jul 1966	159	32.3	Fresh	31.4	6.7	7.6	0.8	Stock	0.0 9.1 31.1	9.1 31.1 32.6	Brown Clay Blue Clay Grey Limestone
468 Morris, R., Con. 4, Lot 18 West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Dec 1965	159	34.4	Fresh	32.9	8.5	11.6	1.1	Stock	0.0 29.9 29.9 32.3 32.3	29.9 32.3 32.4	Clay Clay, Gravel Niagara Rock
469 Beamer, D., Con. 4, Lot 19, West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Jun 1954	143	29.6	Fresh	27.7	9.1	9.1	1.3	Stock	0.0 27.7	27.7 29.6	Clay, Boulders Niagara Rock
1794 Katsoulis, A., Con. 4, Lot 20, West Lincoln Twp. (Formerly Gainsborough Twp.)	185	May 1968	159	36.6	Fresh	35.1	8.8	10.7	0.8	Domestic and Stock	0.0 7.3 7.3 32.9 32.9 35.1 35.1	7.3 32.9 35.1 36.9	Brown Clay Blue Clay Blue Clay, Gravel Grey Limestone

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TABLE H1-1, SUMMARY OF WATER WELL DATA

Sheet 1 of 4

WELL OWNER NAME WELL & LOCATION No.	GROUND LEVEL M (± 0.5)	DATE DRILLED MM YY	WELL DIAM (mm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
1800 Underside, M. Con. 4, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Aug 1968	159	30.2	Fresh	29.6	9.5	19.8	0.8	Domestic and Stock	0.0	4.6	4.6 Brown Clay 4.6 13.7 Blue Clay 13.7 29.3 Red Clay 29.3 30.5 Grey Limestone
1867 Fleming, V. Con. 3, Lot 17 West Lincoln Twp. (Formerly Gainsborough Twp.)	184	Apr 1969	159	35.1	Fresh	35.1	9.1	12.8	0.8	Domestic and Stock	0.0	12.2	12.2 Brown Clay 12.2 33.5 Red Clay 33.5 34.8 Sand, Packed 34.8 35.1 Gravel
1861 Augustyn, R. Con. 2, Lot 18, West Lincoln Twp. (Formerly Gainsborough Twp.)	182	Dec 1969	159	39.6	Fresh	39.9	10.7	11.6	1.1	Domestic and Stock	0.0	31.1	0.0 31.1 Clay 31.1 35.1 Stones 35.1 39.6 Sand and Gravel, Packed 39.6 39.9 Rock
2004 Stedens, J. Con. 4, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	187	Aug 1970	159	30.8	Fresh	29.9	11.6	13.7	0.8	Domestic and Stock	0.0	6.7	0.0 6.7 Brown Clay, Packed 6.7 23.8 Blue Clay, Soft 23.8 29.9 Red Clay, Pebbles 29.9 30.9 Grey Limestone, Layered
2174 Fais, M. Con. 2, Lot 17, West Lincoln Twp. (Formerly Gainsborough Twp.)	170	Oct 1971	159	40.2	Fresh	36.0	8.5	29.0	0.5	Stock	0.0	6.7	0.0 6.7 Brown Clay, Packed 6.7 19.8 Grey Clay, Soft 19.8 27.4 Red Clay, Soft 27.4 35.1 Brown Clay, Gravel, Hard 35.1 36.8 Grey Hardpan, Gravel, Hard 36.8 40.2 Grey Rock, Layered

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TABLE H1-1, SUMMARY OF WATER WELL DATA

Sheet 4 of 4

WELL OWNER NAME WELL & LOCATION No.	GROUND ELEVATION (m ASL)	DATE DRILLED MM. YY.	WELL DEPTH (m)	WATER FINDO (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM TO (m)	MATERIALS DESCRIPTION
2164 Boulton, Ron Con. 4, Lot 19 West Lincoln Twp. (Formerly Gainsborough Twp.)	187	Apr 1972	159	26.2	Fresh	26.5	9.8	9.8	0.8	Domestic	0.0 3.1 Brown clay 3.1 22.9 Blue Clay 22.9 24.4 Stones, Clay 24.4 25.9 Stones, Gravel 25.9 26.5 Rock	
2386 Ellis, G. Con. 2, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.)	178	Aug 1973	159	34.7	Fresh	34.8	6.1	11.6	1.2	Stock	0.0 25.9 Grey Clay 25.9 34.4 Red Clay, Gravel 34.4 34.8 Shale and Gravel	
2338 Beaver, K. Con. 3, Lot 19, West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Dec 1973	159	32.3	Fresh	32.3	9.1	13.7	0.8	Domestic	0.0 11.6 Brown Clay, Packed 11.6 31.7 Red Clay, Soft 31.7 32.3 Grey Shale, Broken	
2348 Underwood, E., Con. 4, Lot 28 West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Mar 1974	159	33.5	Fresh	32.2	8.5	13.7	0.8	Domestic	0.0 9.8 Brown Clay, Packed 9.8 28.7 Red Clay, Soft 28.7 32.8 Grey Clay, Gravel Hard 32.8 33.8 Grey Limestone, Layered	
2391 Kapellas, A., Con. 3, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Sep 1975	159	38.5	Fresh	30.5	11.6	12.2	-	Domestic	0.0 29.9 Grey Clay 29.9 38.5 Shale	

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TABLE H1-1, SUMMARY OF WATER WELL DATA

Sheet 5 of 6

WELL OWNER NAME WELL & LOCATION No.	CONTRACT NUMBER (a) (b) (c)	DATE DRILLED (d) (e) (f)	WELL DIAM. (g)	WATER DEPTH (h)	WATER QUALITY	CASING DEPTH (i)	STATIC LEVEL (j)	PUMPING LEVEL (k)	PUMP RATE (l/s)	WATER USE	FROM (m)	TO (n)	MATERIALS DESCRIPTION
2931 Borden B. Con. 3, Lot 28 West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Jun 1976	159	33.8	Fresh	33.8	9.8	22.2	1.1	Domestic and Stock	8.8 1.5 9.1 9.1 32.8 32.8 32.9 32.9	1.5 Brown Clay, Packed 9.1 Grey Clay, Dense 32.8 Brown Clay, Packed 32.9 Brown Clay, Gravel, Packed 33.8 Grey Shale, Layered	
2779 Tenny Poultry Farms Limited Con. 4, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.) (not able to locate)	186	Nov 1978	159	31.2	Fresh	31.1	10.7	14.6	1.5	Domestic	8.8 28.8 30.5 30.5	28.8 Grey Clay 30.5 Clay, Gravel 31.7 Niagara Rock	
2755 Douries, B., Con. 4, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Apr 1979	159	29.6	Fresh	29.6	9.5	13.7	1.1	Stock	8.8 9.1 29.1 29.1 29.4 29.4	9.1 Grey Clay, Packed 29.1 Brown Clay, Dense 29.4 Grey Shale, Layered 31.7 Grey Limestone, Layered	
2837 Esauville, J., Con. 1, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.)	178	Jul 1980	152	35.1	--	34.4	4.9	24.4	8.8	Stock	8.8 29.8 34.1 34.1	29.8 Grey Clay 34.1 Clay and Stone 35.1 Rock	
2858 Schneider, D.F., Con. 2, Lot 19, West Lincoln Twp. (Formerly Gainsborough Twp.)	183	Jun 1981	198	38.2	Fresh	38.2	7.6	19.8	1.1	Domestic	8.8 2.7 21.3 21.3 25.8 25.8 30.7 30.7	2.7 Brown Clay 21.3 Grey Clay 25.8 Red Clay 30.7 Clay, Gravel 39.3 Rock	

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TABLE H1-1, SUMMARY OF WATER WELL DATA

Sheet 1 of 1

WELL NAME AND WELL LOCATION No.	CASE NO. (a) (b)	DATE DRILLED MM YR	WELL DIAM. (in)	WATER FIND (ft)	WATER QUALITY	CASING DEPTH (ft)	STATIC LEVEL (ft)	PUMPING LEVEL (ft)	PUMP RATE (L/s)	WATER USE	FROM TO (a) (b)	MATERIALS DESCRIPTION
7974 Barrow, F. Com. 4, Lot 28, West Lincoln Twp. (formerly Wainborough Twp.)	185	Jul 1982	152	31.7 32.6	Fresh	30.5	9.8	10.7	1.51	Domestic	0.0 28.8 Gray Clay 28.8 38.5 Clay and Gravel 38.5 32.6 Niagara Rock	

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H2 SUMMARY OF WATER USE DATA

H2.1 EXPLANATION OF WATER USE DATA

The following includes water use information obtained from residents in the vicinity of the Preferred Site which is summarized on Table H2-1. The bulk of this information was obtained from a door-to-door survey completed in August and September 1986. Examples of the field survey forms are shown in Figures H2-1 and H2-2. Supplementary information was provided from the Phase 4A field survey.

TABLE H2-1

SUMMARY OF WATER USE DATA

EXPLANATORY NOTES

1. Assessment Roll No. - the number assigned to a parcel of land for tax purposes, see Map H2-1
2. Lot - lot number situated in the Township of West Lincoln
3. Conc. - concession number situated in the Township of West Lincoln
4. Water Source - source of water supply used on the parcel of land as follows:
 - Dr - drilled well
 - Du - dug/bored well
 - Cr - cistern, rainwater
 - Ct - cistern, trucked water
 - Cr,t- cistern, rainwater and trucked water
 - P - pond
 - S - stream or creek
 - Sp - spring

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5. Water Treatment - type of water treatment as follows:
- c - chlorination
 - s - water softener
 - f - filter
 - uv - ultra violet light
 - o - other
 - d - distillation
 - n - none
6. Potable - domestic drinking water use
7. Non-Potable - domestic water use other than drinking, such as washing, bathing, cleaning and toilet use,
8. Stock - stock watering, including all types of farm animals
9. Other - other types of water use, including irrigation, spraying, wash water for cleaning barns and equipment, commercial and community use
10. Not Used - includes abandoned as well as potentially usable water sources
11. Remarks - general comments on water use, water quality and related comments

NOTE: Water Consumption estimated for the following:

Residential water use - 275 L/d/person*

Lawn/Garden Watering - 1100 L/household/d**

Drinking Water - 2 L/d/person***

Agricultural water use

- Milk cow (including washing)	136 L/d*
- Steer/Dry Cow	55 L/d*
- Horse	55 L/d*
- Hog	7 L/d*
- Sheep	7 L/d*
- Chickens (100)	23 L/d*
- Turkeys (100)	45 L/d*
- Dog (kennel use per dog)	10 L/d***
- Rabbit	2 L/d***
- Goat	7 L/d***
- Geese (100)	45 L/d***
- Ferret	2 L/d***

Commercial water use

- Oxbow Restaurant	5000 L/d***
- Wellandport Community Centre (based on 3000 L/d on weekends)	857 L/d***

* from Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems (MOE, 1982).

** assumes lawn and garden area of 0.1 ha and 100 mm soil moisture deficit from June - August.

*** estimated water consumption.

TABLE H2-1
SUMMARY OF WATER USE DATA

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PAGE 1 of 13

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
5-122	20	4	Dr	n	✓	✓				- MOE well 2924. Household water use 2750 L/d - dog kennel water use 100 L/d
			Dr	n					✓	- MOE well 1794, for future kennel use.
			P (6)	n					✓	- Ponds for future recreational use, i.e., trailer park.
5-123	20	4	Dr	n	✓	✓	✓			- No MOE record - Well supplies 2 homes. - household water use 3850 L/d, supplies residence on 5-123-1 and 5-123 - Livestock use 820 L/d
			Dr	f	✓	✓				- MOE well 2348, supplies duplex household water use 2750 L/d
			P(3)						✓	- Previously supplied cattle.
5-123-1	20	4								- See 5-123
5-124	20	4	Cr,t P	n	✓	✓			✓	- Household water use 1925 L/d - Planned to dig out pond
5-125	19	4	Cr	f	✓	✓				- Household water use 4125 L/d
			Cr P	n		✓			✓	- Cistern for watering garden - Pond not used
5-140	20	4								- No water use, cultivated land
6-111	21	2	Dr	n			✓			- No MOE record, well drilled about 40 years ago, well depth 40.2m, depth to bedrock 39.0m, original static water level 4.3m - Livestock water use 2750 L/d - Good water quality, no sulphur smell, contains minerals - Drop in water level about 6.1m during Welland Canal construction.
			Dr						✓	- Abandoned
			Cr,t	n	✓	✓				- Household water use 2200 L/d
6-114 (interview refused)	20	3	Dr		✓	✓	✓			- MOE well 447, 37.2m deep, *use reported as domestic and stock on well record. - Interview refused - Oil/gas well reported on MNR Map. F-16
			C							
6-149	21	1	Du						✓	- No MOE record, very old well - Stone lined well, filled in and abandoned - Old homestead on property was torn down.
6-177	21	1								- No water supply at Bethel Church - Water is brought in.
6-198	21	2	Dr	n			✓			- No MOE record, well at least 25 years old and about 48.8m deep, current SWL is about 7.6m, livestock water use 5500 L/day - Water quality hard and sulphurous
			Du	n	✓	✓				- No MOE record, very old hand dug well about 6 to 9m deep, static water level near surface, supplies house occasionally and for watering flowers

TABLE H2-1
SUMMARY OF WATER USE DATA

1	2	3	4	5	6 7 8 9 10					11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
6-198 (cont'd)			Cr,t	n	✓	✓				- Household water use 2475 L/d, includes supply from dug well
			Cr,t	n	✓	✓				- Household water use 1925 L/d (for rented residence on property)
			P (3)	n			✓		✓	- Livestock drink from one pond, variable water use - 2 ponds not used
6-227	21	1	Cr		✓	✓				- Household water use 1375 L/d
6-255	21	1	Dr						✓	- No MOE record, very old well, not used
			Dr						✓	- No MOE record, very old well, abandoned, buried under soil
			Du	c	✓	✓				- No MOE record, very old stone lined well, used as cistern - Well diameter about 3m, well depth 4.6 to 6.1m - Household water use 1925 L/d
			P						✓	- Spring fed pond about 1.2m deep previously supplied cattle and for watering garden.
6-270	21	1	Cr,t	n	✓	✓				- Household water use 2200 L/d
6-302	20	3	Dr	n	✓	✓				- MOE well 2531, well depth 33.8m, household water use, 2750 L/d - Good water quality, no sulphur smell, no rust staining
			Dr	n	✓	✓	✓			- MOE well 448, livestock water use 4665 L/d occasional domestic use - Good water quality, slight rust staining, water quality is hard.
			Cr	n			✓			- Secondary source for turkey barns, usage included with well No. 448
7-2	21	1	Dr						✓	- No MOE record, gas well drilled in 1920's, was flowing very sulphury water, was plugged with wooden stump and abandoned.
			Dr						✓	- No MOE record, flowing water well reported along west side of property near old buildings that were torn down, well plugged and covered over - Not sure if drilled or dug well
										- Seepage area reported on property. See Fig.5-1
7-3-5	21	1	Cr,t	f	✓	✓	✓			- Household water use 1650 L/d - Livestock water use 330 L/d
7-14	19	2	Dr						✓	- No MOE record - Well 75 years old - Well depth 28.7m, bedrock at 28.0m - Water quality good, no sulphur smell, water becomes murky before storms - Water level dropped about 2.1m during Welland Canal construction in 1969 - Previously used well for cattle, planned for cattle use in future.
	19	2	Cr,t	n	✓	✓				- Household water use 2475 L/d
			P	n					✓	- Not used, previously used by cattle

TABLE H2-1

SUMMARY OF WATER USE DATA

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
7-15	19	2	Dr	s, f	✓	✓				- MOE well 2858 - 39.3m deep - High iron and sulphur content, household water use 8172 L/d - Noticeable increase in iron and sulphur content after earthquake in 1982 or 1983, reported that several farms in area had similar problems
			Dr						✓	- No MOE record, well is about 60 years old, water quality was good, well is capped and abandoned
			Cr			✓				- Cistern for washing vehicles only, variable usage
			P					✓		- Pond water used for spraying
			Du						✓	- No MOE record - Dug well is very old, likely built with house - About 9m deep - Water quality good, harder than rainwater - Was used for drinking and non-potable domestic use was disconnected from house in 1980 - Dug well not used
7-16	19	2								- Cultivated field
7-20	18	2	Dr						✓	- No MOE record - Greater than 50 years old, abandoned, collapsed at surface
			Du						✓	- No MOE record - About 50 years old, not used - Dug well diameter about 0.9m
			C						✓	- Not used - Was previously filled with water from sump pump in basement and used for drinking and non-potable domestic use - Residence vacant at time of survey
7-21	18	2	Dr	n		✓	✓			- MOE well 1961 - 39.9m deep - Water quality hard, no sulphur odour - Livestock water use 2750 L/d - Also supplies toilet in house
			Dr						✓	- No MOE record, very old well, 5cm diameter casing - Water level dropped in 1969 during Welland Canal construction - Had to abandon well and construct new well
			Cr, t		✓	✓				- Household water use 1650 L/d - Not used
7-22	18	2	C						✓	- Abandoned cistern at old homestead site
			P						✓	- Field is cultivated - Not used
7-92	20	1	Du	n	✓	✓				- No MOE record, well completed in 1982 - Well diameter is 0.9m and 9.1m deep, static water level about 6.1m - Household water use 1650 L/d
	20	1	P (on 7-143)	c, f	✓	✓				- Pond located on north side of 7-143, supplies house on 7-92 household water use included with dug well, chlorine added periodically, water filtered through gravel bed into wet well at pond. - Pond is 4.3m deep

TABLE H2-1
SUMMARY OF WATER USE DATA

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
7-93	20	1	S	n			✓			- Cattle occasionally drink from Welland River - Livestock water use is variable
			P						✓	- Pond was previously used for cattle, not currently used.
7-93-1	19	1	P (on 7-143)	f	✓	✓	✓			- Pond located on south side of 7-143 - Water filtered through gravel bed into wet well at pond, pond is 4.3m deep - Household water use 2475 L/d - Livestock use on 7-143
7-93-2	19	1								- Vacant land - No interview
7-93-3	20	1	P (on 7-94)	n		✓				- Pond on 7-94 supplies residence on 7-93-3 and 7-94, water taken from pond via wet well - Household water use 1650 L/d for residence on 7-93-3 - Bottled water for drinking is brought in - Previously used pond water for drinking
7-94 (interview refused)			P			✓				- Pond supplies residence on 7-94 and 7-93-3 - Water taken via wet well - Pond previously used for drinking, was discontinued 2 years ago - Pond is about 10 - 15 years old, was cleaned out 4 years ago - Water level fluctuates but has never gone dry
			Du						✓	- Dug well is stone lined, use not known
			C						✓	- Interview refused, information provided by neighbour - Cistern abandoned
7-94-1	17	1								- Cultivated land - No interview
7-94-5	18	1	S	n						- Welland River occasionally used for watering cattle and agricultural spray water - Water usage is variable - Springs reported near Welland River at south end of property
7-95	17	1	Cr,t	n	✓	✓				- Household water use 1925 L/d
7-95-1	17	1	Du	n		✓	✓			- No MOE record, well completed in 1983 or 1984, well is 16.8m deep, well was dry immediately after completion - Livestock water use 680 L/d, well serves primarily stock, emergency house supply, project increased water use
			Cr,t	d	✓	✓				- Household water use 1925 L/d, distill drinking water
7-96	17	1	Sp	c	✓	✓			✓	- Spring is flowing year round, chlorine occasionally added, some nitrate in water - Water quality turns bad in spring when Welland River floods area around water supply - Household water use, 2475 L/d - Also used for irrigation occasionally
			S	n					✓	- Welland River used for irrigation, variable usage.

TABLE H2-1
SUMMARY OF WATER USE DATA

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1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
7-97	16	1	Dr	n			✓			- MOE well 2837 - Well depth 35.1m - Faint sulphur smell to water - Livestock water use 510 L/d
			Du						✓	- No MOE record, water level near surface - Not used
			Cr,t	n	✓	✓				- Household water use 2200 L/d
			P (3)	n			✓			- 3 ponds on property used by animals, pond depths 1.5 - 1.8m - Livestock, water use is variable
7-97-5	16	1	Cr,t	n	✓	✓				- Household water use 1650 L/d
7-98	16	1	Cr,t	c	✓	✓				- Usage for community is variable, groups of up to 200 people served on weekends - Water use 857 L/d
			C						✓	- Not used
7-99	16	1	Dr	n	✓	✓				- No MOE record - Well completed several years ago, well is 34.7m deep, static water level 4.3m - Water quality is hard, no sulphur smell - Used for house
			Cr,t	n	✓	✓				- Cistern used for house - Total household water use 1925 L/d - Gas well on property
7-143	19	1	Dr						✓	- No MOE record, very old well, 36.6m deep - 5cm diameter surface pipe - Not used, serves as emergency supply for house, previously supplied cattle
			Dr						✓	- No MOE record, very old well - 15cm diameter well casing - Livestock water use 10880 L/d
			Cr,t	n	✓	✓				- Household water use 2200 L/d
			P	c	✓	✓				- On north side of property, supplies 4 residences on properties 7-92, 7-144, 7-240 and 7-240-5
			P		✓	✓	✓			- On south side of property - Supplies residence on 7-93-1 and barn on 7-143 - Backup source of water for cattle
7-144	20	1	Du						✓	- No MOE record, stone lined dug well is very old, well is 4.6 to 6.1m deep. - Well not used
			Cr			✓				- Rain filled cistern supplies house, household water use included with pond
			P (On 7-143)	n	✓	✓				- Pond on 7-143 supplies household on 7-144, water pumped from pond via wet well, water filtered through gravel bed, pond is 4.3m deep - Household water usage 2475 L/d
7-145	18	1	Dr						✓	- No MOE record, well is old, and 36.6m deep, well is not used
			P						✓	- Not used
										- No residence on property

TABLE H2-1
SUMMARY OF WATER USE DATA

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
7-148	17	1	Dr	n	✓	✓	✓			- No MOE record, well completed 9 years ago, 25.9m deep, current static water level 7.6 to 9.1m - Water quality is high in iron, no sulphur smell - Household water use 2200 L/d - Livestock water use 350 L/d
			Du						✓	- no MOE record, stone lined, not used, water level about 0.9 m from surface, well diameter 1.5 to 1.8 m.
			Du						✓	- Abandoned and filled in - Gas well on property
7-149	16	1	Dr	n	✓	✓	✓			- No MOE record, 15cm diameter casing, current static water level 6.7m, supplies poultry barns and back-up water supply to one residence, also supplies 7-149-5 - Livestock water use 5400 L/d - Household water use included with cistern
	17	1								
			Dr						✓	- Abandoned
			Ct			✓	✓			- Livestock water use included with drilled well
			Cr,t		✓	✓				- Household water use 2475 L/d
			Cr,t		✓	✓				- Supplies second residence household water usage 2040 L/d
			p							- Abandoned and filled in
			-							- Spring reported along Beaver Creek, was used in past by other residents
7-149-5	17	1	Dr (on 7-149)	n	✓	✓				- Well on 7-149 supplies grain elevators, water use variable - Spring reported on property, drained by tile bed
7-149-6	17	1	Cr,t	n	✓	✓				- Household water use 1925 L/d - Gas well on property
7-150	16	1	Cr,t	n	✓	✓				- Household water use 1375 L/d
7-150-1	16	1	Cr,t	n	✓	✓				- Household water use 1925 L/d
7-150-5	16	1								- Cultivated field
	17	1								
7-151	16	1	Cr	n	✓	✓	✓			- Household water use 2200 L/d, backup supply for livestock
			S				✓			- Creek and cistern supply a couple of horses - Livestock water use 110 L/d
7-152	16	1	Du				✓			- No MOE number, well is more than 10 years old, was not used by previous owner, occasionally used for livestock on 7-151
			Cr		✓	✓				- Household water use 1650 L/d
			p			✓				- Pond used for watering garden
			-							
7-153	16	1	Cr,t	c,f	✓	✓				- Household water use 2475 L/d
7-154	16	1	Cr,t	n	✓	✓				- Water usage 2475 L/d - Plan to construct larger cistern, and plan to build swimming pool in near future
			S							- Beaver Creek used for watering garden
7-223	16	1	p						✓	- Pond not used
	17	1	S						✓	- Stream not used

TABLE H2-1
SUMMARY OF WATER USE DATA

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
7-240	20	2	Dr	n					✓	- No MOE record, more than 20 years old, not currently used, was used for livestock and agricultural spray water - Well depth 36.6m
			Dr						✓	- No MOE record, old well, surface pipe diameter 5cm, well was flowing and supplied cattle, well no longer flows and is not used.
			Du	n	✓	✓				- No MOE record, stone lined hand dug well, 9.1m deep - Household water use 2200 L/d
			C						✓	- Abandoned cistern
			P (on 7-143)	c	✓	✓				- Pond on 7-143 supplies residence on 7-240 - Pond is 4.3m deep, water pumped from pond via wet well, water filtered through gravel bed - Water usage included with dug well - Chlorine occasionally added to pond
7-240-5	20	2	Du	n	✓	✓				- No MOE record, well completed 1982, 9.1 m deep - Water slowly filled well after completion - Well provides a backup water supply for household use.
			P (on 7-143)	c	✓	✓				- Pond on 7-143 supplies residence on 7-240-5 - Pond is 4.3m deep, water pumped from pond via wet well, water filtered through gravel bed - Primary supply to residence - Household water use 2475 L/d
7-244	17	2	Dr	n			✓			- no MOE record, more than 20 years old, about 30.5m deep - Water quality hard, occasionally has sulphur smell - Livestock water use 11,500 L/d
			Dr	n			✓			- MOE well 2124, 40.2m deep, current static water level is about 18.3m - Water use included above
			Cr,t	n	✓	✓				- Household water use 2200 L/d
			Cr,t	n			✓			- Livestock water use included with drilled wells
			P	n		✓				- Pond used for watering lawns and gardens, water use is variable - Two gas wells on property
7-245	16	2	Dr	n	✓	✓	✓			- MOE well 2306, 34.7m deep - Supplies household during winter, household water use 1650 L/d - Livestock water use 190 L/d - Water pressure dropped when gas well completed on adjacent property
			Dr						✓	- No MOE record, very old well previously used for barn, abandoned
			Cr	n	✓	✓				- Supplies household in summer, household water use included with drilled well
			Cr	n		✓				- Separate cistern for toilet
7-246	16	2	Du						✓	- No MOE record, very old well filled with refuse, abandoned
			Du						✓	- No MOE record, very old well, water level at surface, abandoned

TABLE H2-1
SUMMARY OF WATER USE DATA

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
7-247	16	2	Dr	n			✓			- MOE record 431, well completed in 1958, well depth 31.1 - 32.3m, well completed 0.6m into bedrock - Originally was flowing well, stopped flowing when gas well drilled on property to southwest, current static water level is about 3m from surface - Livestock water use 4200 L/d - Water level in well dropped during Welland Canal construction.
			Dr						✓	- No MOE record, very old well originally flowing well, filled in and abandoned 29 years ago
			Du	n	✓	✓				- No MOE record, very old, stone lined, dug well, static water level at about 3 m from surface
			Cr,t		✓	✓				- Household water use 1650 L/d including dug well water use.
			C						✓	- Abandoned cistern
			P						✓	- Pond not used
			S						✓	- Previously cattle would drink from ditch running through property - Not used at present
7-264	20	2	Dr	n			✓			- No MOE record, well drilled about 15 years ago, 39.6m deep, static water level in well is about 7.3m - Livestock usage 5500 L/d - Water has sulphur smell, can't use for washing vehicles, leaves white film, good supply, never runs out of water.
			Cr,t	n	✓	✓				- Household water use 1925 L/d
			S						✓	- Not used
7-268	17	3	P						✓	- Not used
7-269	18	2								- No water use reported
7-270	17	2								- No water use reported - Spray water obtained from pond on adjacent property, ~17,800 L used for spraying from adjacent property in 1986.
			P						✓	- Not used
7-271	17	2	Cr,t	f,d	✓	✓		✓		- Household water use 2750 L/d - Cistern occasionally used for agricultural spray water
			P (2)	n				✓		- 2 ponds used for agricultural spray water, 68,100 to 90,800 L of spray water used in 1986
7-272	16	2	Dr	c,s		✓	✓			- MOE well 430, well depth 34.4m - Livestock water use 8670 L/d
			Dr						✓	- No MOE record, previously supplied house, abandoned
			C						✓	- Not used
10-11	19	4	Dr	n	✓	✓	✓			- Use bottled water for potable supply - MOE well 469, well depth 29.6m - Livestock water use 5250 L/d - Household water use 3025 L/d
10-11-1	19	4								- No water use reported, is vacant lot

TABLE H2-1
SUMMARY OF WATER USE DATA

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
10-11-2	19	4	Dr (on 10-11) Ct	s s	✓ ✓	✓ ✓				- MOE well 469, located on adjacent property, 10-11 supplements household water supply - Household water use 2200 L/d
10-11-5	19	4	Cr,t	c	✓	✓				- Household water use 1650 L/d - Planned increase in water use, i.e., swimming pool to be built
10-16	18	4	Dr						✓	- No MOE record, well completed in 1948 or 1949, 30.5m deep - Original static water level 6.1m from ground surface - Well was previously used to supply barn, not presently used
			Ct		✓	✓				- New cistern recently completed - Household water usage 1650 L/d
			C						✓	- Old cistern 2.4m diameter and 3.0m deep, water had sulphur smell, most noticeable in spring, was constructed as shallow dug well, has been abandoned and filled in.
	18	4	P						✓	- Pond not used
10-16-5	18	4	Cr,t	n	✓	✓	✓			- Household use 2200 L/d - Livestock use 3 L/d
10-17	18	4	Dr	n	✓	✓				- No MOE record, well appears to be old, well depth 45.7m - Household use 2200 L/d - Plan to have livestock in near future
10-17-1	18	4								- Vacant land, no interview
10-76	19	3	Dr	c			✓			- No MOE record, well completed in 1982, 37.5m deep - Water quality 80 grains of hardness (1142 ppm) - Livestock water use reported as 6800 L/d - Well water became murky in 1984 when drilling of test holes along Schram Road for OMMC - Well completed to top of a rock shelf, original static water level about 9.1m from surface
			Dr						✓	- No MOE record, well drilled in 1964, well depth 38.4m - Noticeable sulphur content in water, 112-118 grains of hardness (1598 - 1684 ppm) - Well not used.
			Dr						✓	- No MOE record, old well located under silo, about 18.3m deep, well abandoned
			Cr,t	n	✓	✓				- Household water use 2760 L/d
10-77 (interview refused)	19	3	Cr,t		✓	✓				- Interview refused for Phase 4B study, information from interview completed for Phase 4A study - Cistern built about 1083, cistern is 4.6m deep and 1.5m wide, is brick lined - Mostly rainwater in cistern - Water quality hard, no distinct taste - Residence is occupied on part-time basis
10-80 (partial interview)	18	3								- Partial interview completed - Refusal to complete interview - Cultivated land, old homestead site at west end of property - No apparent water use

TABLE H2-1
SUMMARY OF WATER USE DATA

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
10-81	17	3	Dr	n		✓	✓			- MOE well 1867, well depth 35.1m - Livestock usage 414 L/d - Well supplies washroom in house - Original static water level 9.1m
			Cr	n	✓	✓				- Household water use 1925 L/d
			P	n			✓			- Occasional use of pond water by cattle, livestock water use included with drilled well.
10-82	16 17	3 3	Dr	n	✓	✓	✓			- No MOE well record, well drilled more than 20 years ago, well depth 36.6m, - Current static water level is 6.1m - Livestock water use 3575 L/d, household water use, see cistern - Household water use 2200 L/d
	16 17	3 3	Cr	n	✓	✓				
10-84	15	3	Dr (on 10-86)	n	✓	✓				- Well located on 10-86 - Household water use 2200 L/d
10-85	15	3	Dr (on 10-86)	n	✓	✓				- Well located on 10-86 - Household water use 2200 L/d
10-86	15	3	Dr	n			✓			- No MOE record, well about 70 years old, well depth 32.0m, bedrock found at 30.5m, original static water level about 2.1m, current static water level about 5.2m - Livestock water use 920 L/d - Water quality hard with high iron, water gets cloudy during spring
			C						✓	- Abandoned cistern.
10-100	19	3	Dr	n	✓	✓	✓			- MOE well 446, well depth 35.4m - Water quality good, no sulphur smell - Household water use 1110 L/d - Supplies cattle in winter - Livestock water use is variable
			P (2)	n			✓		✓	- One pond supplies cattle during summer, one pond not used - Livestock water use is variable
			C			✓				- Gas well on property
10-101	19	3	Dr	n	✓	✓				- Non potable household use 1365 L/d - MOE well 2330, well depth 32.3m - Household water use 2475 L/d - Water quality hard with some rust staining, excellent quality - Water turned black with sulphur smell after oil and gas well drilled on adjacent property 4 to 5 years ago, water is now clear and sulphur smell not as noticeable. - Cistern used for washing only
			Cr	n		✓				
10-103	19	3	Ct	n		✓				- Household usage 1650 L/d - Commercial (garage) water use not known - Buy distilled water for drinking
10-105	18	3	Dr	c,s	✓		✓			- No MOE record, well drilled about 40 years ago, well depth 36.6m - Household water use 1650 L/d - Livestock water use 2590 L/d - Well supplies livestock in winter - Treated well water smells sulphury
			Cr,t	n	✓	✓				- Household usage included with drilled well
			P	n			✓			- Supplies livestock in summer, livestock water use included with drilled well.

TABLE H2-1
SUMMARY OF WATER USE DATA

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
10-106	17 18	3 3	Dr	n	✓	✓				- No MOE record, well depth is 42.7m - Household usage 1375 L/d - Well was previously used to supply livestock
			Dr						✓	- No MOE record, well depth is 27.4m - Well is presently not used - Well was used last year by neighbour for livestock watering as emergency supply - Gas well reported in Phase 4A study - Cistern at east side of house not used - Not used - Household water use 1650 L/d
10-108	17	3	Cr,t	n	✓	✓			✓	
10-110	16	3	Dr	c,s,f	✓	✓	✓			- No MOE record, well completed in 1958-59, well depth about 31.4 to 32.0m - Livestock water use 6900 L/d - Household water use 1650 L/d - Drinking water is distilled
10-110	16	3	Dr	s,d	✓	✓				- MOE well 2391, well depth 30.5m - Household water use 2200 L/d
10-111	15	3	Du	f,uv	✓	✓				- No MOE record, well completed more than 80 years ago, well diameter 1.2m - Water at top of well in spring drops to near bottom of well in summer - Household usage 1650 L/d - Bacteria contamination of well after highway widened and ditch moved closer to well, ultraviolet light installed as result of complaint
10-155	19	4								- Cultivated field
10-156	19	4	Ct	n	✓	✓				- Household water use 2200 L/d - Planning to use rainwater when eavestroughing is finished - No MOE record, very old well, brick lined, about 2.4m deep, was previously used for watering garden, has been abandoned and filled in.
			Du						✓	
10-158	19	4	Cr,t	n	✓	✓				- Household use 1375 L/d
			C						✓	- Cistern at barn was previously used for horses, not used at time of study
10-160	18	4	Dr				✓			- MOE well 468, supplies livestock (note: information from interview during Phase 4A, no mention of well during Phase 4B interview) - No MOE record, supplies livestock (note: information from interview during Phase 4A, no mention of well during Phase 4B interview) - Household water use 2475 L/d
			Dr				✓			
			Ct	s	✓	✓				
			P				✓			- Livestock water use from pond and drilled wells to 9,000 L/d
			Du						✓	- No MOE record, stone lined well, not used, water level observed at about 1.2m from surface in August 1986.
10-161	17 18	4 4	Dr/Du						✓	- No MOE record, well is older than 15 years old, well is not used, not sure if dug or drilled well
			P						✓	- Previously used for agricultural spray water, shallow pond about 0.3m deep, dries up in summer - Property is vacant

TABLE H2-1
SUMMARY OF WATER USE DATA

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1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
10-162	17	4	Dr/Du Cr,t P (2)	n n	 ✓	 ✓	 ✓	 ✓	 ✓	- No MOE record, old well reported near barn has been abandoned, no other information available, not sure if dug or drilled. - Household water usage 2200 L/d - Livestock water use 12,245 L/d - Pond behind barn 3.7m deep - Pond near road 1.8m deep
10-163	16	4	Du(2) Ct C	n n	 ✓	 ✓	 ✓	 ✓	 ✓	- No MOE records, two dry wells excavated by backhoe, gravel backfill around dry wells, both wells are 7.0m deep - 1.8m of crumbly clay overlying blue "gummy" clay - Small seep of water encountered at 6.1m, flow of water noted from southeast to northwest from a point about 0.16m in diameter at southeast side of excavation - Dug wells supply toilet in house only, water is contaminated from driveway runoff - Household water use 2200 L/d - Not used, became contaminated when new ditch constructed along highway
10-164	16	4	Cr,t C	n	✓	✓	✓	✓	✓	- Household water usage 1650 L/d - Old cistern contaminated with soap is not used
10-165	16	4								- No interview, absentee landowner, part-time residents on property
10-166	16	4	Dr	n	✓	✓	✓	✓	✓	- MOE well 2755, well depth 31.7m - Household water use 1650 L/d - Livestock water use 508 L/d - No sulphur taste in water
10-168	16	4	Dr On 10-169)							- Severed lot with barn, no livestock in barn, water use is variable, water supplied from drilled well on 10-169
10-169	16	4	Dr	n	✓	✓	✓	✓	✓	- MOE well 466, well depth 31.4m - Household water use 2200 L/d - Livestock water use 10,050 L/d
10-170	16	4	Dr	n	✓	✓	✓	✓	✓	- MOE well 1800, well depth 30.5m - Household water use 1925 L/d - Livestock water use 400 L/d
10-171	16	4	Dr Dr Dr P	n n n	 ✓ ✓	 ✓ ✓	 ✓ ✓	 ✓ ✓	 ✓ ✓	- MOE well 467, well depth 32.6m - Household water use 1650 L/d - Livestock water use 22,165 L/d - MOE well 2004, well depth is 30.6 m - Household water use 2475 L/d - No MOE record, well completed in March 1986, well depth 34.1m - Original static water level about 7.3m - Well tested at 7.58 L/sec. - Well used for drinking water by workers - Livestock water use 88,000 L/d - Pond previously used for livestock, pond water was chlorinated, not presently used
10-171-5	16	4	Dr	n	✓	✓	✓	✓	✓	- No MOE record, well depth about 33.5m - Supplies restaurant, 100-200 people served per day - Commercial water use 5000 L/d (estimated)

TABLE H2-1
SUMMARY OF WATER USE DATA

1	2	3	4	5	6	7	8	9	10	11
Assessment Roll No.	Lot	Concession	Water Source	Water Treatment	Water Use					REMARKS
					Potable	Non-Potable	Stock	Other	Not Used	
10-172	15	4	Cr,t p	f	✓	✓	✓			- Household water use 2200 L/d - Livestock water use, 246 L/d - Drinking water filtered - Keeps a few ducks in pond
10-172-5	15	4	Dr				✓			- No MDE record, located at barn - No interview, could not locate owner - Information provided by neighbour - assumed to be used for livestock water, quantity not estimated
10-227	19	4								- Vacant building lot
10-228	19	4	Dr		✓	✓				- MDE well 2164, well depth 26.5m - Household use 2200 L/d
10-235	17	4								- Cultivated field
10-236	17	4	Dr	s,f	✓	✓		✓		- No MDE record, well is very old - Well depth about 27.4m - Household water use 2200 L/d - Good water quality - Unspecified agricultural water use
10-237	17	4								- Cultivated field
10-238	16	4	Du						✓	- No MDE record, old stone lined well, is abandoned and filled in.
10-239	16	4	Du Cr,t		✓	✓			✓	- No MDE record, stone lined well, is abandoned and filled in - Cistern for gun club use at clubhouse, water usage is variable
10-241	15	4	Dr	n					✓	- No MDE record, well drilled with portable power auger to 9.4m depth, thin gravel layers about 0.1m thick encountered at depths of 6.7m and 7.6m - Water encountered at 6.1m - Static water level about 1.8m when well completed - Well not used, clay pushed up inside bottom of casing - Bring in drinking water

FIGURE H2-1

H-27
EXAMPLE FORM

OWMC PHASE 4B

WATER USE AND WATER WELL STUDY

CONTACT RECORD

Interview No. :

Assessment Roll No. :

Interviewee :

Date _____

Time

Caller

Comments

General Comments

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

H-28

OWMC PHASE 4B
WATER USE AND WATER WELL STUDY

CONDUCTED BY
GARTNER LEE ASSOCIATES LIMITED

PROJECT 85 - GW - 1

AUGUST 1986

INTERVIEW # _____

H-29

QUESTION

RESPONSE

INTERVIEW INFORMATION

- 1 Name of the respondent? _____
- 2 Respondent's address? _____

- Ontario, _____
- Telephone no () - _____
- 3 Interviewers name _____
- 4 Date of interview? (YY.MM.DD) _____
- 5 Time of interview? (military time) _____

LOCATION INFORMATION

- 6 Study Area?
- 1 = Site
- 2 = Adjacent
- 3 = Vicinity
- 4 = Access Roads

QUESTION

RESPONSE

LAND OWNERSHIP INFORMATION

To be filled out for each block of assessed land.

7 Assessment Roll
Number?

Lot _____
Conc _____
TWP _____

Owners Telephone No.

(____) ____-____

Owners Name & Address?

Ontario, ____-____

8 Assessment Roll
Number?

Lot _____
Conc _____
TWP _____

Owners Telephone No.

(____) ____-____

Owners Name & Address?

Ontario, ____-____

9 Assessment Roll
Number?

Lot _____
Conc _____
TWP _____

Owners Telephone No.

(____) ____-____

Owners Name & Address?

Ontario, ____-____

10 Assessment Roll
Number?

Lot _____
Conc _____
TWP _____

Owners Telephone No.

(____) ____-____

Owners Name & Address?

Ontario, ____-____

QUESTION

RESPONSE

WATER USE INFORMATION

- 11 How many **water wells** are on this property ? _____
(Mark their locations on the base map)
- 12 How many **oil or gas wells** are on this property ? _____
(Mark their locations on the base map)
- 13 What is your source of **potable or drinking water**? _____
1 = Drilled well 2 = Hand dug well
3 = Bored well 4 = Cistern (truck water)
5 = Cistern (rain filled) 6 = River or stream
7 = Municipal supply 8 = Ponds
9 = Other _____
- 14 How many people use the drinking water at this property? _____
- 15 What is your source of **non-potable domestic water**? _____
1 = Not applicable 2 = Drilled well
3 = Dug or bored well 4 = Cistern (truck water)
5 = Cistern (rain filled) 6 = River or stream
7 = Municipal supply 8 = Ponds
9 = Other _____
- 16 What is your source(s) of **agricultural water**? _____
1 = Not applicable 2 = Drilled well
3 = Dug or bored well 4 = Cistern (truck water)
5 = Cistern (rain filled) 6 = River or stream
7 = Municipal supply 8 = Ponds
9 = Other _____
- 17 How many pigs use this water supply? _____
- 18 How many cattle use this water supply? _____
- 19 How many chickens use this water supply? _____
- 20 How many other animals are there on this property?
Type _____ Number _____

- 21 Do you use a septic tank and weeping field at this property? Y / N / N/A

QUESTION	RESPONSE
22 What is the distance between the weeping field and your drinking water well?	_____ (m)
23 Do you have an (agricultural) waste tank on this property?	Y / N / N/A
24 What is the distance between the waste tank and the drinking water well?	_____ (m)
25 Would you allow sampling of your well/cistern water for laboratory analysis at some later time?	Y / N / N/A

QUESTION

RESPONSE

WELL INFORMATION

To be filled out for each well : water, gas/oil, active or not.

- 26 Type of well? _____
1 = Water well - domestic and drinking
2 = Water well - domestic nonpotable
3 = Water well - agricultural use
4 = Gas or oil well
9 = Other type _____
- 27 Does the well have an official identification number? _____
(e.g. MOE water well number)
- 28 Where is the well located? _____
Lot? _____
Concession? _____
Township? _____
UTM Coordinates _____
(Mark the location on the base map)
- 29 What is the status of the well? _____
1 = In use 2 = Abandoned
3 = Planned for future use
4 = Unlikely to be used in the future
- 30 If not used, what is the reason? _____
1 = Insufficient QUANTITY
2 = Poor QUALITY
3 = Other reason _____

WELL CONSTRUCTION DETAILS

- 31 When was the well constructed? _____
- 32 Who installed it? _____
- 33 How was it installed? _____
1 = Drilled 2 = Bored or augered
3 = Dug by hand 4 = Dug by backhoe
5 = Other method _____
- 34 What is the casing DIAMETER? _____ (m)
- 35 What is the well DEPTH? _____ (m)
- 36 What is the elevation of the casing collar? _____ m a.s.l.
- 37 What was the original static water level? _____ (m)
(metres below grade)

QUESTION	RESPONSE
38 What is the current static water level? (metres below grade)	_____ (m)
39 How is the top of the well finished? 1 = Casing above grade 2 = Casing at grade 3 = Casing below grade (in an open pit) 4 = Pump house over well 5 = Covered by concrete slab or housing (well pit) 6 = Well seal or pitless adaptor 7 = Open casing 8 = Plugged casing 9 = Casing pulled (open hole) 10 = Other	_____
40 Is the well casing accessible (for sampling)?	Y / N
41 Is the well casing vented to the atmosphere?	Y / N
42 What type of pump is in the well? 1 = Submersible 2 = Deep well (jet pump) 3 = Shallow (jet pump) 4 = Hand pump 9 = Other	_____ _____
43 How old is the pump? When was it installed?	_____ _____
44 How is it lubricated? 1 = Oil 2 = Grease 3 = Water	_____
45 What is the depth of the pump intake?	_____ (m)
46 What is the pumping rate?	_____ (L/s gpm)

QUESTION

RESPONSE

TANKS, TREATMENT AND TROUBLES

- 47 What type of permanent storage tank do you use? _____
 1 = Galvanised steel 2 = Glass lined steel
 3 = Plastic 4 = Concrete
 5 = Concrete with plastic liner
 9 = Other _____
- 48 What is the capacity of the storage tank? _____ litres gallons
- 49 Do you use a (a) Chlorinator? Y / N
 (b) Water softener Y / N
 (c) Filter Y / N
 (d) Other water treatment Y / N _____
- 50 Is the treated water used for domestic or agricultural uses? _____
- 51 What type of filter do you use? _____
 1 = Sand 2 = Activated carbon
 3 = Cartridge
 9 = Other _____
- 52 Have you had any problems with this well? Y / N
- 53 What year did the problem occur? _____
- 54 What was the problem? _____
 1 = Insufficient water 2 = Pump failure
 3 = Plugging of the well 4 = Well interference
 5 = Poor water quality 6 = Contamination
 9 = Other _____
- 57 Has any government agency been notified about the problem? _____
 e.g. MOE
- 58 Has the problem been corrected? Y / N
- 58 How was it corrected? _____
 1 = Well deepened 2 = Pump repaired
 3 = New well constructed 4 = Water treatment
 9 = Other _____

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FIGURE H2-2

EXAMPLE FORM

UWMC PHASE 4B
SURFACE DRAINAGE, WATER USE SURVEY

CONDUCTED BY
GARTNER LEE ASSOCIATES LIMITED

PROJECT 86-_____

AUGUST, 1986

WATER USE

- 1 How many **streams**, creeks and drainage ditches are there on this property?
(please mark their locations and directions of flow on the base map)
- 2 How many **ponds** are there on this property?
(please mark their locations on the base map)
- 3 Do the animals on this property drink directly from the stream? Y / N
Does the stream supply an adequate water supply for year round use? Y / N
If not...do you know when and why the supply is inadequate?
- 4 Do the animals on this property drink directly from the pond? Y / N
Does the pond supply an adequate water supply for year round use? Y / N
If not...do you know when and why the supply is inadequate?
- 5 Do you irrigate from the streams and pond on this property? Y / N
Is there an adequate water supply for your irrigation? Y / N
If not...do you know why the supply is inadequate?

SURFACE DRAINAGE AND FLOODING

Comment : please ensure that the streams, creeks and drainage swales are marked on the base map, including the direction of flow.

- 6 What is the maximum depth of water flowing in the swales, creeks and ditches on this property?

Are there any significant high water marks? Y / N
Where and what are they?

When were these observed (dates)?

How many years have you been observing floods on this property?

- 7 Does flooding present a problem in the ditches and swales on your land?
(Please mark the locations of the flooding on the base map.)

- 8 Are any of the flooding problems associated with buildings on your property?
If so... where, when and how frequently?

- 9 If you have flooding in the vicinity of your buildings, is this because of an overflow from a nearby stream or because of poor drainage in the vicinity of the building?

- 10 Do any of the local roads get flooded?
(Please mark the locations on the base map.)

What time of year does this flooding take place?
How frequently does it take place?

- 11 Have any of the local bridges or culverts been improved or reconstructed in recent years?
Where are they located on the basemap?

- 12 Does soil erosion present a problem on this property?
If so....where? Please mark the location on the base map.

Have any conservation measures been taken to correct the erosion problems?
If so....what and where?

- 13 Do the streams flow all year round?
Which ones dry up?
How long are these streams dry ?
(say, how many weeks in the year)

14. Are crops normally grown through the field series? Y / N
Are there any places on the property where cropping is not possible because of poor drainage?
If so, where?
15. Have you ever consulted the Conservation authority, the Ministry of the Environment, the Ministry of Natural Resources, the Ministry of Agriculture or any other government agency regarding flooding or soil erosion on this property?
If so, which agency, when and why?
16. What portion of this property is drained by tiles?
Please mark the area on the map, showing the layout and the location of the outlet, if possible?



I-1

APPENDIX I

SUPPORTING CALCULATIONS

APPENDIX I
SUPPORTING CALCULATIONS
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II GROUND WATER FLOW CALCULATIONS

This appendix provides the methodology and results of ground water flow calculations. These calculations are based on porosities, hydraulic conductivities, and hydraulic gradients determined by hydrogeologic testing, geotechnical testing, and water level measurements during the geoscience program.

II.1 METHODOLOGY

Specific discharge (v) is the rate of ground water discharge through a porous medium per unit area perpendicular to the flow direction. It can be calculated using the following one-dimensional form of Darcy's Law (Freeze and Cherry, 1979, p. 16):

$$v = Ki$$

where K = hydraulic conductivity (m/s)

i = hydraulic gradient

Furthermore, the average linear ground water velocity is expressed as (Freeze and Cherry, 1979, p. 71):

$$\bar{v} = \frac{v}{n}$$

where n = porosity

11.2 RESULTS

The results of the ground water flow calculations are presented in Table 11-1. For each unit or subunit, values of hydraulic conductivity, hydraulic gradient, and porosity are summarized. These are presented in Sections 3.2 and 3.3. The resulting values of specific discharge and average linear ground water velocity are tabulated both in m/a and mm/a.

No calculations were possible for the weathered silt and clay, since the hydraulic conductivity and hydraulic gradient are highly variable and the fracture porosity is unknown. Flow in the weathered silt and clay is further discussed in Appendix 12-4.

TABLE I1-1: SUMMARY OF GROUND WATER FLOW CALCULATIONS

HYDROSTRATIGRAPHIC UNIT	MEAN HYDRAULIC CONDUCTIVITY K (m/s)	AVERAGE HYDRAULIC GRADIENT i	AVERAGE POROSITY n	SPECIFIC DISCHARGE v		AVERAGE LINEAR GROUND WATER VELOCITY $\bar{v}$	
				m/a	mm/a	m/a	mm/a
AQUITARD							
Weathered Silt and Clay*	-	-	-	-	-	-	-
Unweathered Silt and Clay	2E-10	0.25 downward	0.41	0.0016	1.6	0.0038	3.8
Lower Till	2E-8	0.25 downward	0.16	0.16	160	0.099	990
BEDROCK AQUIFER							
Zone A	2E-4	0.0002 southward	0.01**	1.3	1300	130	130,000
Zone B	2E-7	not measured	-	-	-	-	-
Zone C	>2E-5	0.0003 southward	0.05***	>0.19	>190	>3.8	>3800
Zone D	<2E-9	not measured	-	-	-	-	-
Zone E	2E-6	0.0005 southward	0.05***	0.032	32	0.63	631

Notes: 1 m/s = 3.1536E7 m/a
1 mm/s = 3.1536E10 mm/a

Equations: $v = Ki$
 $\bar{v} = \frac{v}{n}$

* This unit has variable hydraulic conductivity, variable hydraulic gradient (transient), and an unknown fracture porosity, no calculations possible

** Fracture porosity estimated using method of Snow (1968) for given hydraulic conductivity and fracture set spacings of 50 mm estimated from field borehole logs.

*** Assumed porosity based on field observations

I2 GROUND WATER FLOW MODELLING

I2.1 INTRODUCTION

Ground water flow at the Preferred Site was modelled using the two-dimensional, finite element flow model called FLONET. The FLONET model is documented in Section I2.2. The purpose of the modelling was twofold:

- (1) to confirm the deep ground water flow pattern interpreted from the hydrogeologic field data, and,
- (2) to establish the nature of shallow (surficial) ground water flow.

Ground water flow at the Preferred Site can be subdivided into shallow and deep flow. Shallow flow is transient in that it is constantly changing in response to changing climatic conditions (i.e. rainfall, evapotranspiration etc.). This is reflected in changes in the water table elevation, which were observed in the shallow standpipe monitors (see Section 3.3.3.2 for a discussion of seasonal water table fluctuations and Appendix F2 for detailed water level measurements). Deep ground water flow through the unweathered silt and clay and bedrock aquifer is considered to be at steady state since the monitors showed only minor fluctuations once they had reached static water levels (Appendix F2). In essence, the shallow flow acts as a buffer for deep flow. Because of this important distinction, deep and shallow ground water flow were separately modelled. The methodology and results are presented in Sections I2.2 and I2.3 respectively.

12.2 FLONET MODEL DOCUMENTATION

This section presents a summary documentation of the FLONET model. It includes sections containing a technical description of the model (12.2.1), the theory on which FLONET is based (12.2.2), and finally a discussion of the model verification (12.2.3).

12.2.1 TECHNICAL DESCRIPTION

AUTHORS: E.O. Frind and G.B. Matanga,
Groundwater Research Institute,
Department of Earth Sciences,
University of Waterloo

COMPUTER SYSTEM/LANGUAGE: IBM 4341/FORTRAN
ATARI 520ST/BASIC
HEWLETT PACKARD 9816/BASIC

MODIFICATIONS: • Conversion to the Atari 520ST/BASIC microcomputer by E.A. Sudicky of the Groundwater Research Institute, University of Waterloo.

• Conversion to the Hewlett Packard 9816/BASIC microcomputer with input/output modifications by R.G. McLaren of Gartner Lee Associates Limited.

MODEL TYPE/FEATURES: • numerical, finite element

- steady-state groundwater flow
- 2-dimensional in cross-section
- porous medium can be heterogeneous and anisotropic
- two-step solution procedure; first step solves for hydraulic head distribution, second step solves for stream function distribution
- hydraulic head solution step can be iterative in order to seek the position of the water table

ASSUMPTIONS: • flow is governed by the Laplace equation

- flow is restricted to be parallel to the plane of the cross-section (i.e. no flow into or out of the face of the cross-section)

INPUT PARAMETERS:

- the profile is fully saturated
- finite-element grid data:
 - 1) node co-ordinates
 - 2) element incidences
- element properties:
 - 1) hydraulic conductivity in X-direction
 - 2) hydraulic conductivity in Y-direction
 - 3) angle of principal direction of permeability
- boundary conditions for hydraulic head and stream function solutions
- optional grid deformation data for iterative calculation of water table position.

OUTPUT:

- a printout of all input data and calculated hydraulic heads, stream functions, average linear ground-water velocities and for the hydraulic head solution, boundary fluxes.
- grid plots (node and element data)
- contour plots of hydraulic head and/or stream functions
- plot of average linear ground water velocity vectors.

REFERENCE: Frind, E.O. and Matanga, G.B., 1985. The dual formulation of flow for contaminant transport modelling: 1. Review of theory and accuracy aspects. Water Resources Research, vol. 21, no. 2, pp. 159-169.

12.2.2 THEORY

A comprehensive review of the mathematical theory, finite-element formulation, and model development is provided in Frind and Matanga (1985).

12.2.3 MODEL VERIFICATION

FLONET was verified at the Groundwater Research Institute, University of Waterloo, by its authors. Further verification testing was performed by Gartner Lee following modifications to the model. This consisted of comparison to exact analytical solutions. Gartner Lee's verification was subsequently checked by Ed Sudicky of the Groundwater Research Institute.

12.3 DEEP GROUND WATER FLOW MODELLING

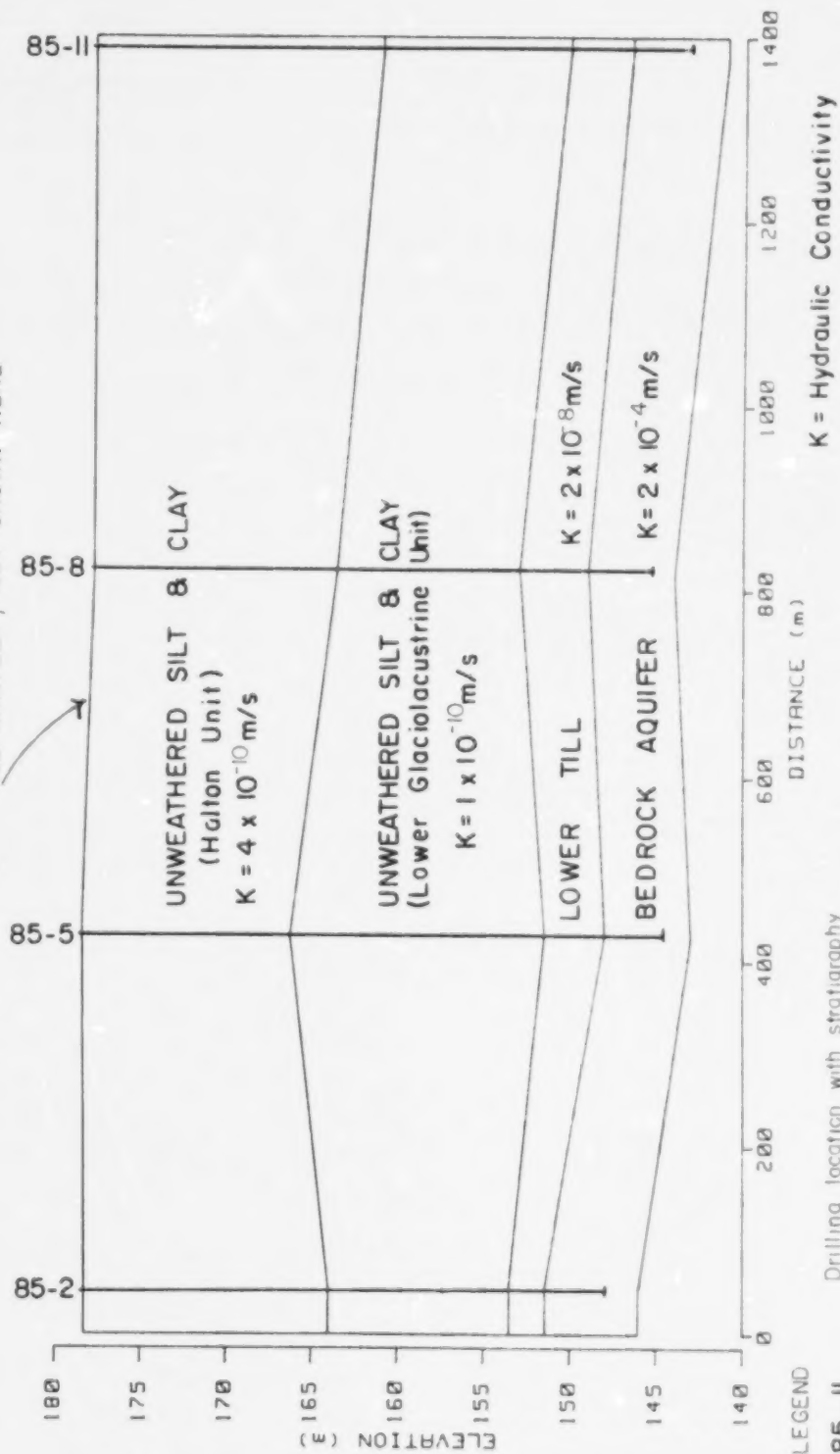
Deep ground water flow was modelled in order to confirm the flow pattern interpreted from the hydrogeologic field data. The comparison is contained in Section 3.3.4. This appendix provides details of the modelling.

A north-south cross-section through the middle of the Preferred Site was chosen so that the results would be comparable to Figure 3-6. Figure 12-1 illustrates the cross-section and the four drilling locations that lie along the section. The geologic boundaries shown in Figure 12-1 were interpreted from the stratigraphic boreholes at these drilling locations, which are also shown. The Upper Glaciolacustrine unit, which contains the shallow flow zone, was modelled separately (Appendix 12.4) and is therefore not shown here.

Hydraulic conductivity values for each geologic unit are shown on Figure 12-1. The values for the Lower Till and Bedrock

Figure I2-1
DEEP FLOW MODELLING CROSS-SECTION AND MATERIAL
PROPERTIES

NOTE - UPPER GLACIOLACUSTRINE UNIT MODELLED
 SEPARATELY, NOT SHOWN HERE



Aquifer are average values determined by hydrogeologic testing, as discussed in Sections 3.2.4 and 3.2.5. Only the upper 6 m (Zone A) of the Bedrock Aquifer was modelled since it is underlain by a lower permeability aquitard (Zone B) that tends to isolate it (Section 3.3.3.2).

The hydraulic conductivities of the Halton Unit and Lower Glaciolacustrine Unit were $4\text{E-}10$ m/s and $1\text{E-}10$ m/s respectively in the simulation. These are within the range of hydraulic conductivities resulting from hydrogeologic testing in the unweathered silt and clay, and also produces the same geometric mean of $2\text{E-}10$ m/s (Section 3.2.3). The values were adjusted slightly from the mean value so that the modelling would produce a closer match with observed hydraulic heads, and probably represents a slight degree of overall variability that was not observed in the hydrogeologic testing at specific depths.

Figure I2-2 illustrates the finite element mesh that was used in the modelling. The elements were triangular and each corner represents a nodal point. Figure I2-3 shows the boundary conditions that were applied to the finite element mesh. The vertical boundaries of the aquitard are assumed to be impermeable; that is, no ground water flow occurs across these boundaries. This is consistent with the predominantly downward gradient in the aquitard below the weathered zone (Section 3.3.3.2). The bottom of the cross-section was also an impermeable boundary based on the presence of a bedrock aquitard (Zone B).

A constant value of hydraulic head was assigned to all nodes along the top of the section and at each end of the bedrock aquifer. The head values were based on observed

Figure I2-2
DEEP FLOW MODELLING FINITE ELEMENT MESH

REFER TO FIGURE I2-1 FOR CROSS -
SECTION DETAILS

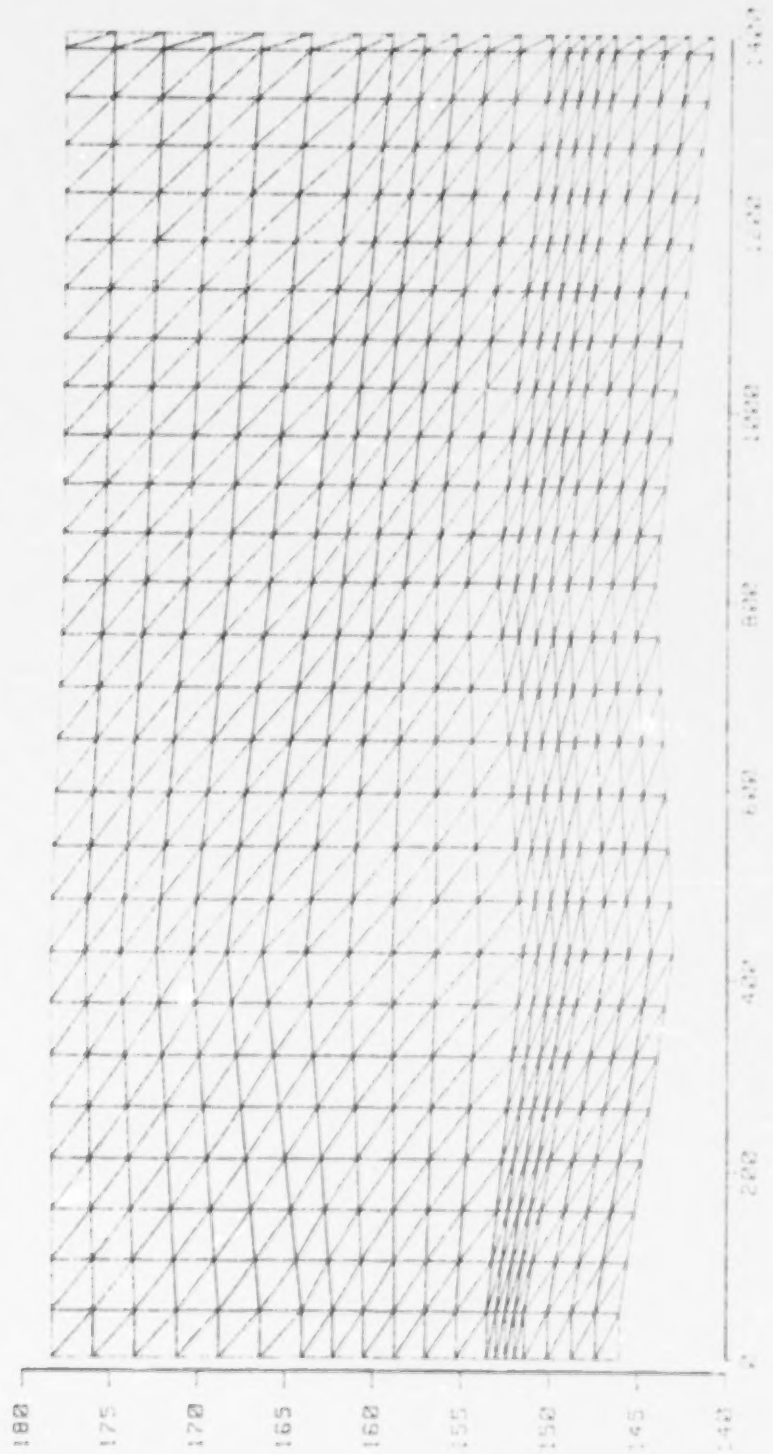
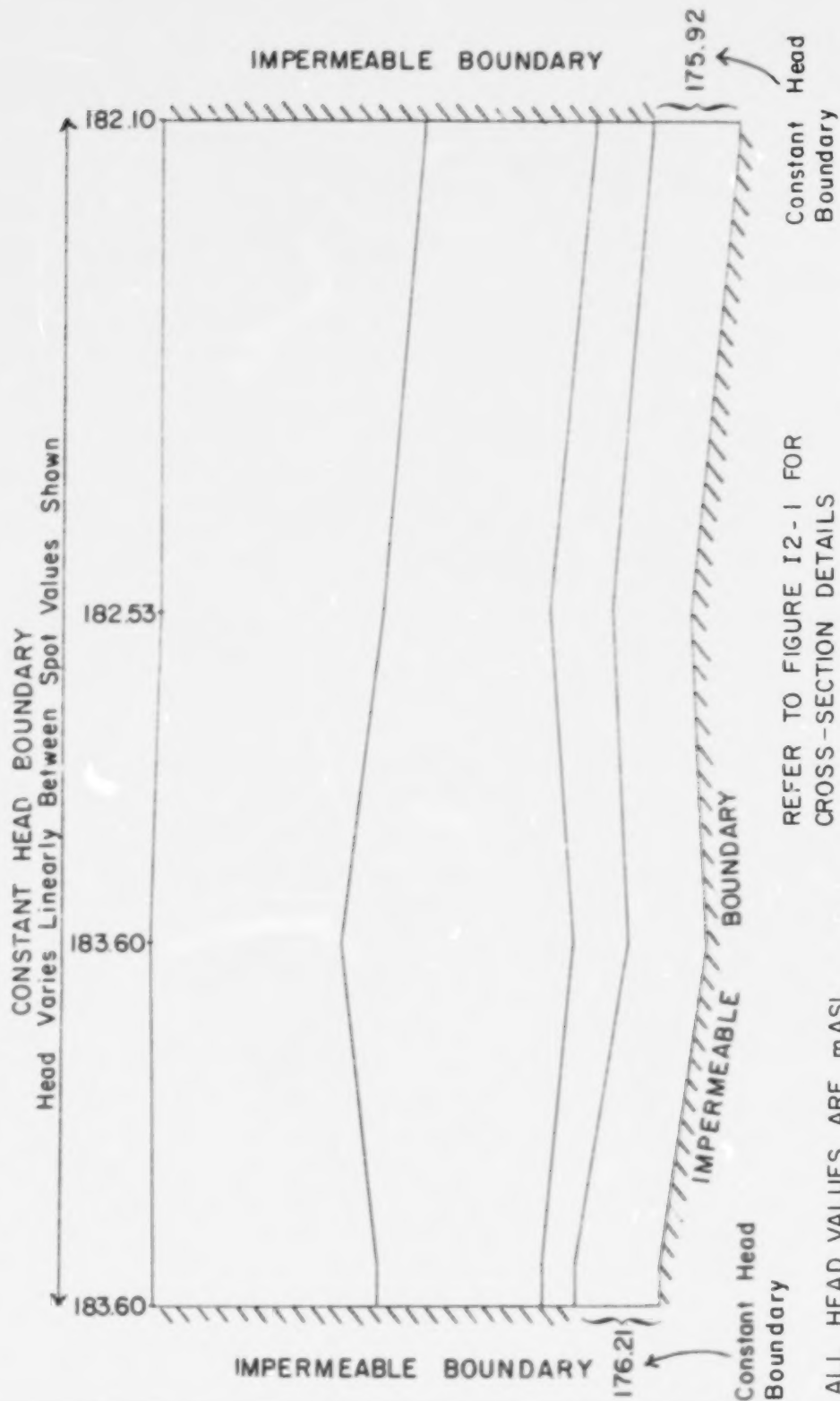


Figure 12-3
DEEP FLOW MODELLING BOUNDARY CONDITIONS



hydraulic heads in the ground water monitors during June 1986 (Figure 3-6 and Appendix F2). Constant head boundaries allow ground water to flow across the boundaries. The rate of flow is calculated by the model.

Figure I2-4 illustrates the results of the ground water flow modelling. Equipotential contours (lines of equal hydraulic head) are shown. Ground water flow is perpendicular to these contours, although the vertical exaggeration of the cross-section must be accounted for.

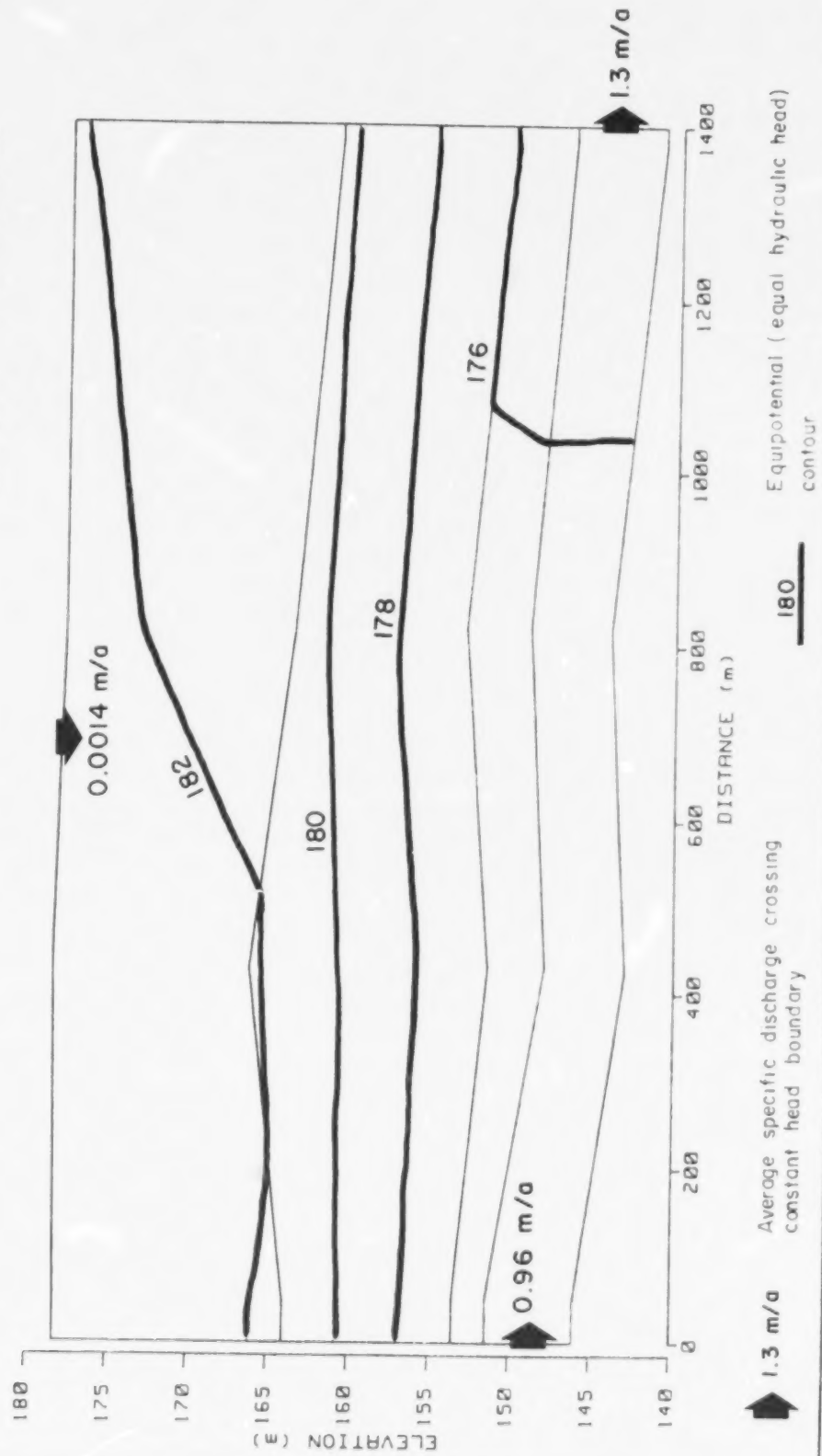
The specific discharges (total ground water flow quantity per unit area perpendicular to flow) crossing the constant head boundaries are shown in Figure I2-4. Comparison of these specific discharges with those calculated using the one-dimensional Darcy's Law equation, shown in Table I1-1, indicates excellent agreement. This confirms that flow in the aquitard and bedrock aquifer can be considered as predominantly vertical and horizontal respectively.

I2.4 SHALLOW GROUND WATER FLOW MODELLING

Shallow ground water flow is known to be transient at the Preferred Site, evidenced by water table fluctuations. One extreme of the range of flow conditions exists when there is infiltration recharging the water table. This occurs during rainfall or snowmelt, for example. The water table is expected to rise quickly to ground surface during recharge as the open fractures, which have a relatively small volume, fill with water. The silt and clay matrix, however, may be much slower to saturate due to its low hydraulic conductivity. Under this condition, the local ridge and swale topography controls

Figure I2-4

DEEP FLOW MODELLING RESULTS - HYDRAULIC HEAD DISTRIBUTION

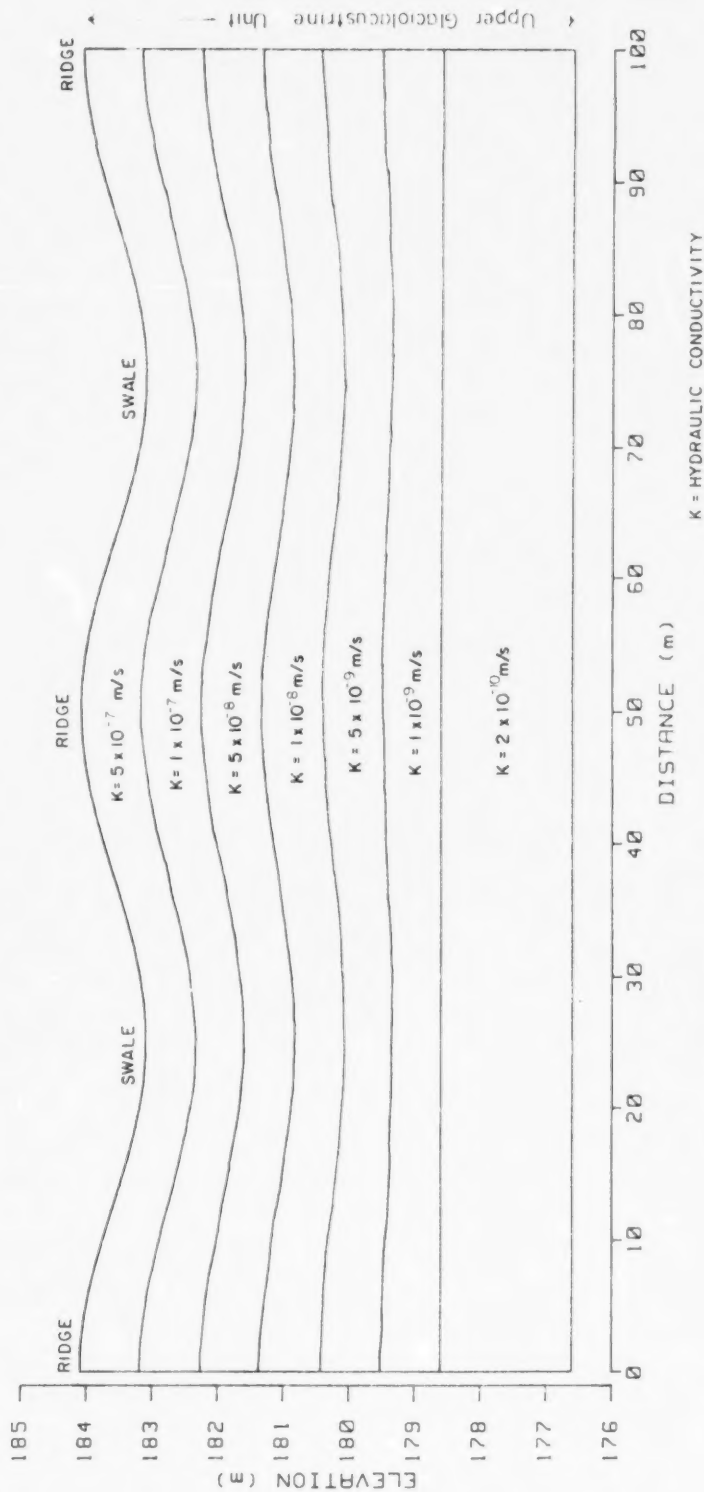
REFER TO FIGURE I2-1 FOR
CROSS-SECTION DETAILS

ground water flow, with recharge at the ridges discharging in the swales. Again because the fractures are volumetrically small, this transient flow condition is expected to dissipate quickly once the recharge ceases. Therefore, the high water table scenario exists essentially only during recharge events, which is a relatively small portion of the year. This scenario was modelled and the results are presented here.

The other extreme of shallow flow occurs between recharge events, the largest portion of the year. During this time, the water table generally exists below the base of the swales. It is expected to be flat to gently undulating in a mute expression of local topography. The water levels measured in the standpipes at the Preferred Site represent this condition (Appendix F2). Because the resulting local lateral gradients are small and because the water table is deeper in the weathered zone where bulk hydraulic gradients are lower, local ground water movement is expected to be very limited. Also, intermediate or regional scale shallow flow is expected to be limited since the site and surrounding area are very flat topographically.

The purpose of modelling shallow flow was to establish the nature of the flow pattern under recharge conditions. The generic cross-section shown in Figure I2-5 was established to represent a typical north-south section through the ridge and swale topography. The overall relief is 1 m and the frequency of the ridges is 50 m, which are typical of the site topography. A total width of 100 m was modelled, and the depth of the section represents the depth to the base of the Upper Glaciolacustrine Unit in the vicinity of drilling location 85-12, which was used as a basis for comparison.

Figure 12-5
SHALLOW FLOW MODELLING CROSS-SECTION AND
MATERIAL PROPERTIES



Figures I2-5 also shows the material properties specified in the modelling. The hydraulic conductivity was stepped from $5\text{E-}7$ m/s near surface down to $2\text{E-}10$ m/s at the base of the section to represent the transition from weathered to unweathered silt and clay. This was felt to be realistic based on the observed decrease in fracture frequency with depth from the surface.

Figure I2-6 illustrates the finite element mesh used in the modelling. Triangular elements were used with the nodes occurring at each corner. Figure I2-7 presents the specified boundary conditions. The left and right boundaries were impermeable since they occur beneath ridge peaks which act as local flow divides; because of the symmetry no flow crosses these boundaries. The lower boundary was specified as a constant flux boundary. The flux value was 0.0014 m/a, a value which resulted from the deep flow modelling (see Figure I2-4). The ground surface was specified as a constant head boundary, with the head values equal to the topographic elevation. This simulates a water table at surface, which is the expected recharge scenario.

Figure I2-8 presents the hydraulic head distribution that resulted from the simulation. This clearly shows hydraulic head to be reasonably constant with depth. This trend was also noted at the two drilling locations where detailed water level monitoring was undertaken in the weathered silt and clay; namely 85-1 and 85-12 (see Figures 3-3 and 3-4, and Appendix F2). Constant hydraulic head with depth suggests predominantly lateral flow.

Figure I2-6

SHALLOW FLOW MODELLING FINITE ELEMENT MESH

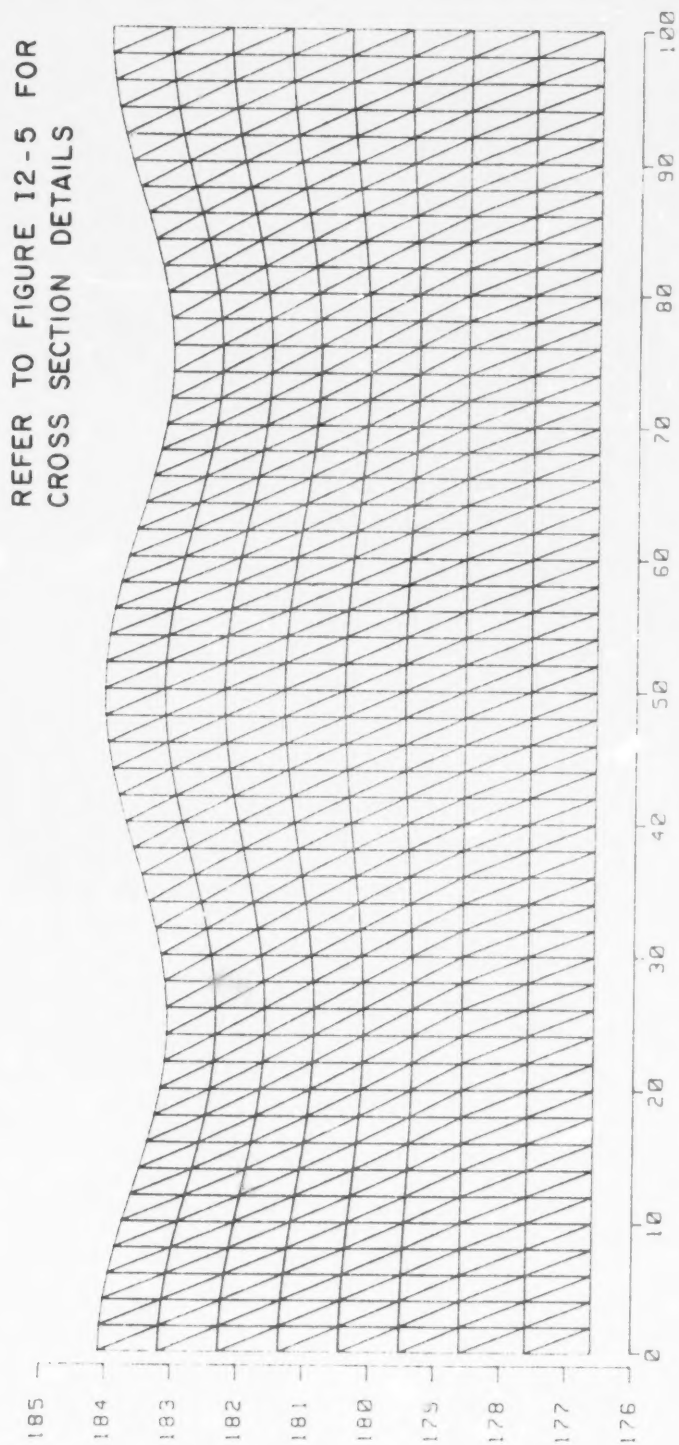
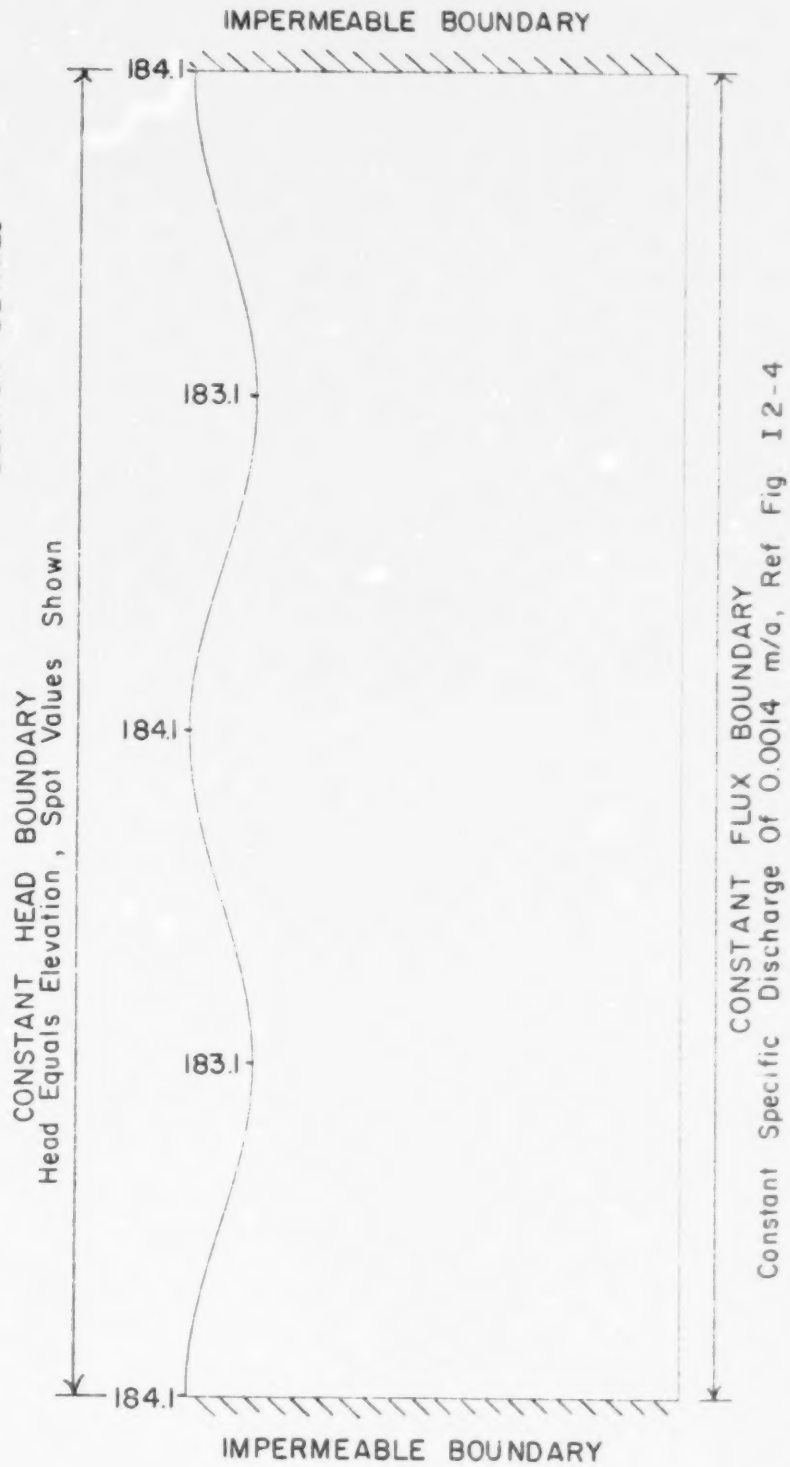


Figure I2-7
SHALLOW FLOW MODELLING BOUNDARY CONDITIONS

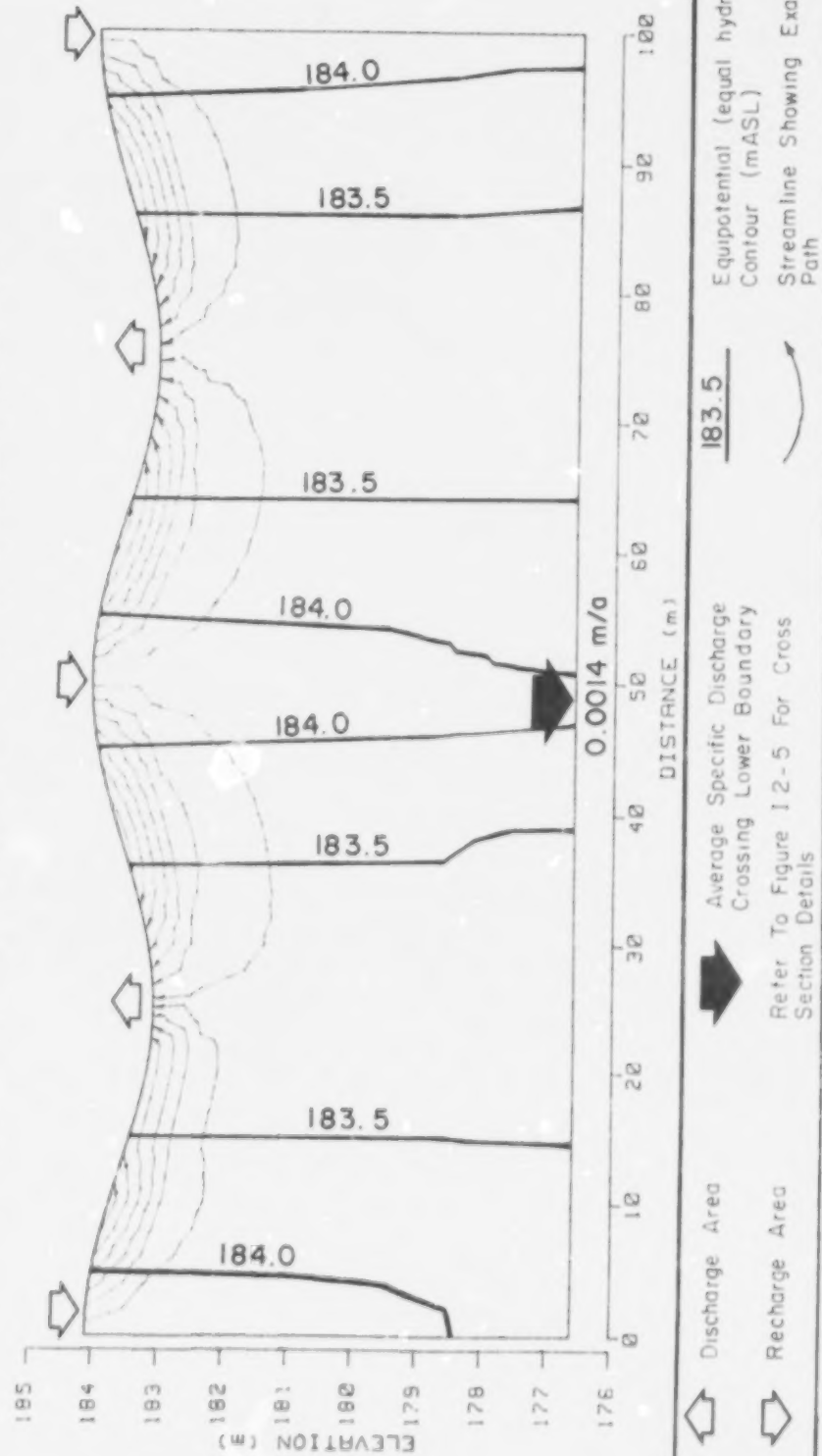
REFER TO FIGURE I2-5 FOR CROSS -
SECTION DETAILS



ALL HEAD VALUES ARE MASL

Figure I2-8
SHALLOW FLOW MODELLING RESULTS - HYDRAULIC HEAD
AND STREAMLINE DISTRIBUTIONS

AVERAGE SPECIFIC RECHARGE RATE AT RIDGES = 0.092 m/a
AVERAGE SPECIFIC DISCHARGE RATE AT SWALES = 0.079 m/a



Streamline distributions were also calculated using the FLONET model to better define the actual flow pattern. The results are shown in Figure I2-8. Streamlines show examples of the actual paths of ground water flow. They are calculated such that there is an equal discharge of ground water between any two adjacent streamlines. Thus, closer streamline spacing is indicative of greater flow quantities. Examination of Figure I2-9 suggests that the bulk of recharge occurs at the ridges and the bulk of the discharge occurs at the swales. Flow from ridges to swales is predominantly in the upper 3 metres. As expected, a very small proportion of the recharge is transmitted to depth. In fact, the specific discharge below 3 m depth is so small that no streamlines occur within the 100 m cross-section width.

Also shown on Figure I2-8 are average specific infiltration and discharge rates at surface, and the specific discharge from the base of the section. As expected, the specific discharge from the base of the Upper Glaciolacustrine Unit shown in Figure I2-8 equals the average specific recharge to the Halton Unit shown in Figure I2-4.

13 WATER BUDGET

Water budget calculations are used to partition quantities of water that reach the ground surface as precipitation. The pathways by which precipitation can be routed include surface runoff, evapotranspiration, shallow flow to surface water systems, and ground water recharge.

A water budget has been prepared for the Preferred Site using long term meteorological data from Welland, Ontario. The results are representative of average long term conditions only. The results are summarized in Table 13-1.

The method detailed by Thornthwaite and Mather (1957) was used for the water budget calculation. This technique assumes that the soil moisture is depleted in a nonlinear manner and replenished in a linear manner, and calculates a value for actual evapotranspiration based on the precipitation and the change in moisture status of the soil.

The mean annual precipitation at Welland is 938 mm. (Note: all values are per unit surface area). The potential evapotranspiration is calculated to be 637 mm/a. However, when the soil moisture storage is considered, the average actual evapotranspiration is calculated to be only 558 mm/a, leaving a water surplus, when subtracted from the precipitation, of 380 mm/a. While the bulk of this water (estimated to be about 243 mm/a) is likely to leave the site as runoff during the spring snowmelt, the remainder of approximately 137 mm/a will result as direct surface runoff during rainfall, or infiltrate into the ground.

TABLE 13-1: WATER BUDGET CALCULATION

LOCATION: Welland, Ontario

METHOD: Thornthwaite and Mather (1957),
Nonlinear Loss of Soil Moisture

CALCULATED MINIMUM ANNUAL SNOWMELT RUNOFF
(Based on Thornthwaite and Mather 1957): 243 mm/a

SOIL MOSTURE STORAGE: 100 mm/a

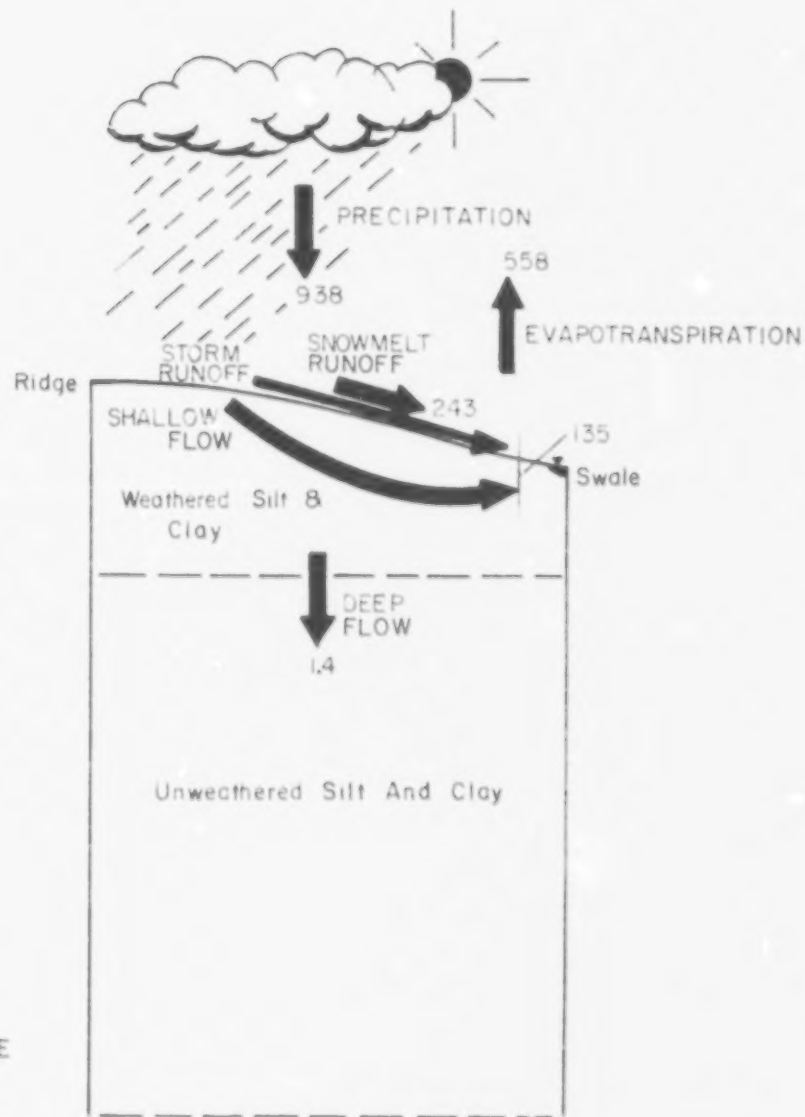
MONTH	MEAN TEMP	MEAN PRECIP	POTENTIAL EVT	ACTUAL EVT	SURPLUS WATER
Jan.	-4.9	83.0	0	0	1
Feb.	-4.5	68.2	0	0	1
Mar.	0.5	84.6	1	1	66
Apr.	7.2	77.5	34	34	152
May	13.2	71.6	78	78	76
June	18.7	72.2	117	106	38
July	21.5	61.1	139	94	19
Aug.	20.7	91.2	123	99	10
Sep.	16.7	85.5	84	84	5
Oct.	10.8	70.8	46	46	2
Nov.	4.8	79.9	15	15	6
Dec.	-1.7	92.4	0	0	3
Year		938.0	637	558	380

It is known from ground water modelling that an average of slightly less than 2 mm/a flows through the unweathered silt and clay unit to recharge the bedrock aquifer (Section 3.2.3). Deducting this from the 137 mm/a identified as infiltration results in a total of about 135 mm/a that is discharged to the local surface drainage system by direct rainfall runoff or by lateral flow in the local flow system to the surface drainage swales.

Figure I3-1 shows a schematic summary of the water budget calculations presented in this section.

Figure I3-1

Schematic Diagram Of Water Budget Calculations



NOT TO SCALE

*Values are millimeters per year per unit area.
Calculations represent long term averages only.*

APPENDIX J

GROUND WATER CHEMISTRY RESULTS

GROUND WATER CHEMISTRY RESULTS
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TABLE J1-1

SUMMARY OF GROUND WATER CHEMISTRY DATA:
GENERAL CHEMISTRY AND MAJOR IONS

Table J1-1 presents the results of field and laboratory analyses of general chemical indicators and major ions on ground water samples from the Preferred Site. Major ions were considered to be those parameters whose concentrations consistently exceeded 1 mg/L. The general chemical indicators of pH, temperature and electrical conductivity were measured in the field. All other parameters on Table J1-1 are the results of laboratory analyses. All concentrations are in mg/L (ppm) unless otherwise noted.

Also included in Table J1-1 is the percent charge balance. This was calculated from the major ions using the equation:

$$(\sum \text{meq/L cations} - \sum \text{meq/L anions}) / (\sum \text{meq/L cations} + \sum \text{meq/L anions}) \times 100$$

where $\sum$ means to sum all of the numbers and meq/L means milliequivalents per litre. The percent charge balance can be either positive or negative depending on whether cations or anions are in excess. The cations included in the calculation were Ca^{+2} , K^{+} , Mg^{+2} , Na^{+} and Sr^{+2} . The anions included were F^{-} , Cl^{-} , SO_4^{-2} and alkalinity (as HCO_3^{-}). To convert alkalinity as CaCO_3 to HCO_3^{-} divide by 0.8202. The percent charge balance is used as a check on the accuracy of the analyses. As per standard practice, analyses with charge balances in excess of 10% were considered invalid.

TABLE J1-1 : SUMMARY OF GROUND WATER CHEMISTRY DATA: GENERAL CHEMISTRY AND MAJOR IONS

GENERAL CHEMISTRY AND MAJOR IONS																		
MONITOR #	SCREENED INTERVAL (depth in m)	DATE SAMPLE	COMPOUNDS															
			pH in field	Temperature in field (DEC C)	Conductivity in field (micro/cm)	Total Dissolved Solid (mg/L)	Alkalinity (mg/L as CaCO3)	Dissolved Inorganic Carbon (mg/L)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)	Si (mg/L)	Sr (mg/L)	F (mg/L)	Cl (mg/L)	SO4 (mg/L)	CHARGE BALANCE
85-1-1	34.4 to 37.5	17-Jun-86 26-Aug-86	7.77 7.32	10 10	1990 1920	2060 2270	60 50	15 22	255 252	1 1	96.8 99.1	162 149	4.09 4.13	5.62 5.68	2.18 1.95	17.5 18.9	1198 1190	2.4 1.8
85-1-3	25.91 to 26.91	17-Jun-86 26-Aug-86	9.88 9.29	11 13	1450 1400	1160 1230	59 34	16 12	46.2 53.1	18 8	20.7 20.7	211 194	2.36 2.67	1.25 1.43	1.09 1.05	30.5 31.8	710 575	-10.2 -2.2
85-1-10	2.33 to 5.33	17-Jun-86 26-Aug-86	7.01 7.03	11 12	6460 6100	8940 11200	652 639	150 180	369 335	6 5	1130 1090	329 292	7.81 6.42	7.55 7.33	4.91 4.68	10.2 17.5	5546 5280	-1.2 -1.7
85-1-11	8.8 to 9.84	17-Jun-86 26-Aug-86	7.49 7.62	13 12	5040 5000	6170 6540	284 328	75 100	284 307	6 7	503 531	690 605	18.5 13.4	6.47 6.91	3.45 3.48	19 20.3	4000 3700	-2.2 0.8
85-1-14	2.2 to 2.5	17-Jun-86 11-Sep-86	7.80 7.76	13 7	3440 5680	3520 4380	880 819	240 176	60.5 113	5 6	505 543	249 328	6.66 16.6	3.28 3.35	2.91 2.91	8.2 7.5	1560 2000	4.9 4.8
85-1-15	2.7 to 3	17-Jun-86 11-Sep-86	7.93 7.28	13 7	3860 6240	3520 4750	846 854	220 170	113 54.8	6 2	543 454	328 261	16.6 4.69	3.35 2.79	2.91 2.65	7.5 6.5	2000 1820	-3.7
85-1-16	3.7 to 4	17-Jun-86 11-Sep-86	7.46 7.25	12 7	5700 10500	6760 7820	758 868	160 100	198 206	9 5	883 884	460 435	6.83 5.5	5.65 5.56	4 3.76	11 9.4	4230 3800	0.9 3.6
85-1-17	4.5 to 4.8	17-Jun-86 11-Sep-86	7.36 6.97	12 7	6320 11600	8090 9020	678 650	155 34	365 325	11 6	1010 1020	431 367	6.99 5.54	7.31 7.6	4.73 5.28	12.3 11	5860 4570	6.4 3.4
85-1-18	5.2 to 5.5	17-Jun-86 11-Sep-86	7.34 7.75	10 7	8090 15900	10400 12200	594 648	175 55	426 380	14 9	1110 1030	923 907	7.17 5.46	8.9 8.41	6.36 6.67	17.5 15.9	7500 6370	-4.8
85-1-19	6 to 6.3	17-Jun-86 11-Sep-86	7.41 7.27	10 7	7470 15200	10600 11400	530 538	50 34	473 321	15 7	1110 945	866 706	25.2 5.82	8.95 7.44	5.45 7.55	18.7 10.8	7000 4230	-1.3 -6.2
85-1-20	6.7 to 7	17-Jun-86 11-Sep-86	7.49 7.17	12 7	7460 14300	10200 11100	446 434	35 81	393 377	9 6	1040 1070	763 694	7.26 7.27	9.05 8.56	5.82 6.94	18.5 18.2	6560 5970	-2.6 1.3

For explanation of comments see last page of this table

TABLE J1-1 : SUMMARY OF GROUND WATER CHEMISTRY DATA: GENERAL CHEMISTRY AND MAJOR IONS

GENERAL CHEMISTRY AND MAJOR IONS																			
MONITOR #	SCREENED INTERVAL	DATE SAMPLE	COMMENTS	pH in field	Temperature in field (DEC C)	Conductivity in field (umhos/cm)	Total Dissolved Solid (log/L)	Alkalinity (log/L as CaCO3)	Dissolved Inorganic Carbon	Ca (log/L)	K (log/L)	Mg (log/L)	Na (log/L)	Si (log/L)	Sr (log/L)	F (log/L)	Cl (log/L)	SO4 (log/L)	CHARGE BALANCE
85-1-21	7 65 to 7 96	17-Jun-86		7.41	13	7450	9990	426	115	383	10	1130	697	6.88	9.21	5.82	19.5	6810	-2.8
		11-Sep-86		7.42		14500	12300	400	75	315	6	964	523	4.99	7.7	6.94	18.5	6180	-7.6
85-2-4	15 5 to 16 6	12-Jun-86	F	7.78	12	1750	2510	208	52	175	6	181	314	5.93	3.61	2.18	24	1530	3.2
		26-Aug-86		7.73	13	3175	3060	100	26	145	2	92.4	495	4.37	3.8	2.19	20.7	1770	-3.6
85-3-1	32 18 to 34 69	12-Jun-86		7.33	13	2300	2480	89	25	378	3	114	138	3.99	8	2.67	41.2	1370	4.4
		26-Aug-86		7.58	10	2150	2870	91	24	336	1	112	131	3.73	7.9	2.27	42.4	1520	-3.9
85-3-10	2 3 to 5 3	12-Jun-86		7.05	13	9560	13100	618	110	423	11	1760	545	6.63	10.4	7.27	10.5	9370	-4.5
		26-Aug-86		7.23	11	10000	19100	632	172	393	7	1710	466	6.01	10.1	7.6	11.4	8630	-3.2
85-6-1	36 49 to 39 47	18-Jun-86		7.54	10	2420	2540	64	17.5	353	4	107	148	3.75	8.97	2.73	43	1500	-1.1
		18-Jun-86	A	7.54	10	2420	2520	54	17	359	3	108	157	3.6	8.98	2.54	40	1500	0.5
		21-Aug-86		7.3	10	2100	2960	62	11	363	3	115	146	4.09	9.41	2.18	45.9	1540	-0.7
		21-Aug-86	A	7.3	10	2100	2660	62	40	358	4	110	148	4.21	8.95	2.14	43.7	1590	-3.0
85-8-4	15 16 to 16 16	18-Jun-86		8.01	10	4320	4440	72	19	352	4	283	505	3.82	7.43	2.36	27.5	3120	-3.2
		21-Aug-86		7.73	12	4250	5050	82	11	336	3	295	512	4.3	7.66	2.74	28.1	2990	-0.8
85-8-8	24 66 to 25 38	18-Jun-86		8.04	11	1450	1180	40	12	91.1	1	31.4	206	3.29	1.98	1	36.2	760	-4.5
		18-Jun-86	A	8.04	11	1450	1200	40	12.5	92.9	1	31.7	204	3.21	1.93	1.18	33.2	760	-4.2
		21-Aug-86		8.19	11	1600	1160	36	13	91.2	2	37.3	193	3.64	1.91	0.97	37.3	690	-0.2
		21-Aug-86	A	8.19	11	1600	1260	36	8	87.4	2	36.1	185	3.29	1.84	0.99	36	710	-3.4
85-8-10	2 43 to 5 33	18-Jun-86		7.21	11	7410	14700	648	165	401	9	1410	342	5.86	7.93	6	8.5	7370	-4.7
		18-Jun-86	A	7.21	11	7410	10500	666	165	403	9	1520	348	5.88	8.07	5.82	8.5	6680	2.9
		21-Aug-86		6.95	11	7000	12200	662	160	413	10	1460	343	7.09	8.65	6.11	8.8	6370	5.0
		21-Aug-86	A	6.95	11	7000	11600	592	170	412	11	1450	337	7.05	8.54	5.88	9.1	6270	4.0
85-8-11	8 45 to 9 45	18-Jun-86		7.42	13	8670	12000	556	140	392	13	1540	578	6.59	8.24	6.73	16.7	8120	-2.6
		21-Aug-86		7.12	12	8800	13800	554	137	400	13	1470	675	9.26	8.76	6.86	22.4	7550	0.4

For explanation of comments see last page of this table

TABLE J1-1 : SUMMARY OF GROUND WATER CHEMISTRY DATA : GENERAL CHEMISTRY AND MAJOR IONS

MONITOR #	SCREENED INTERVAL (depth in ft)	DATE SAMPLE	COMMENTS		pH in field	Temperature in field (DEG C)	Conductivity in field (uohms/cm)	Total Dissolved Solid (g/L)	Alkalinity (log/L as CaCO3)	Dissolved Inorganic Carbon (g/L)	Ca (g/L)	K (g/L)	Mg (g/L)	Na (g/L)	Si (g/L)	Sr (g/L)	F (g/L)	Cl (g/L)	SO4 (g/L)	CHARGE BALANCE
85-10-1	24.85 to	12-Jun-86			7.3	11	2660	2780	84	25	382	3	124	179	4.63	9.99	2.51	49.9	1620	-9.6
	39.85	26-Aug-86			7.44	11	2300	2720	66	16	341	2	113	158	4.15	9.34	2.25	49.1	1650	-5.3
85-10-10	2.85 to	12-Jun-86			7.49	12	1010	762	424	135	188	2	61.6	56	6.19	0.718	0.87	4	181	2.2
	3.65	26-Aug-86			7.4	12	1080	780	438	112	94.7	1	70.9	57	8.98	0.988	0.68	3.3	174	2.3
85-11-4	16.78 to	12-Jun-86			8.39	12	1980	2260	57	12.5	113	15	44	282	3.11	2.98	1.45	32.5	1810	-28.9
	17.7	26-Aug-86			8.47	13	2550	2220	32	7	145	9	56.1	394	3.88	3.13	1.89	34	1420	-3.3
85-12-1	30 to	10-Jun-86			7.68	13	2410	2160	54	15	335	4	96.5	169	5.78	9.75	2.22	29.2	1370	2.8
	41	10-Jun-86			7.68	13	2410	2180	49	22.5	345	5	99.9	155	3.89	9.84	2.36	28.7	1370	3.3
		21-Aug-86			7.35	10	2200	2420	54	20	325	1	101	149	4.26	9.95	2.14	31.9	1420	-0.6
	21-Aug-86				7.35	12	2200	2960	50	15	330	1	100	147	4.11	9.7	2.17	32.3	1420	-0.4
85-12-8	24.55 to	10-Jun-86			8.05	13	1110	920	58	16.5	46.7	1	15.7	179	3.38	0.991	0.91	18.8	540	-5.9
	25.15	10-Jun-86			8.05	13	1110	842	51	16	42.3	1	14.7	235	4.82	1.11	0.94	19.3	510	5.2
		21-Aug-86			8.55	18	1380	886	54	16	46.6	1	17.9	168	3.46	0.947	0.83	21.3	480	43.7
	21-Aug-86				8.55	18	1380	958	59	6	46.8	1	18.3	161	3.65	0.973	0.92	20.9	410	45.2
85-12-10	2.3 to	10-Jun-86			7.37	13	9600	13600	690	210	434	9	1880	469	6.97	10.7	6.54	7.8	8190	2.9
	5.23	10-Jun-86			7.37	13	9680	13600	704	210	428	9	1860	408	6.81	10.7	6.72	7.3	8370	1.4
		21-Aug-86			6.93	11	9500	18700	730	170	420	9	1790	372	7.41	11.3	7.31	10	8230	0.8
	21-Aug-86				6.93	11	9500	18500	766	260	420	6	2450	369	6.73	11.4	7.69	10	8840	0.7
85-12-11	8.35 to	10-Jun-86			7.51	12	7130	9680	452	130	421	12	841	740	8.39	7.86	4.73	14.1	5620	-1.3
	9.45	26-Aug-86			7.7	13	5080	10080	462	115	398	11	766	1060	8.54	8.08	5.14	17.1	5490	2.2
85-12-13	1.2 to	18-Jun-86			7.46	12	5580	7160	274	74	410	2	729	326	7.73	5.82	3.64	4	4250	0.3
	1.5																			
85-12-14	2.2 to	10-Jun-86			7.45	12	9360	12700	558	35	380	4	1840	388	6.48	9.83	6.73	5.9	6880	0.7
	2.5	11-Sep-86			7.78	11	19200	17180	594	51	328	2	1620	333	6.73	9.13	8.05	8.1	8560	-7.1

For explanation of comments see last page of this table

TABLE J1-1 : SUMMARY OF GROUND WATER CHEMISTRY DATA : GENERAL CHEMISTRY AND MAJOR IONS

MONITOR #	SCREENED INTERVAL (depth in m)	DATE SAMPLE	COMMENTS	pH in field	Temperature in field (DEG C)	Conductivity in field (microhm/cm)	Total Dissolved Solid (mg/L)	Alkalinity (mg/L as CaCO3)	Dissolved Inorganic Carbon (mg/L)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)	Si (mg/L)	Sr (mg/L)	F (mg/L)	Cl (mg/L)	SO4 (mg/L)	CHARGE BALANCE
85-12-15	2.7 to 3	10-Jun-86		7.5	12	8560	13600	466	145	398	4	1770	369	6.97	9.12	6.91	8.9	8540	-1.7
		11-Sep-86		7.52	12	17600	14900	442	43	377	2	1810	354	7.42	10.1	8.05	10.2	7780	3.3
85-12-16	3.7 to 4	10-Jun-86		7.36	12	9170	12600	566	145	405	7	1590	478	7.98	8.79	6.73	8.7	8120	-2.4
		11-Sep-86		7.2	11	17600	15100	498	58	414	5	1760	436	7.24	10.8	7.5	10.8	7570	4.4
85-12-17	4.5 to 4.8	10-Jun-86		7.3	12	8560	11200	620	185	386	10	1440	537	6.86	8.4	6	8.7	7560	-2.7
		11-Sep-86		7.14	10	16000	13700	606	34	362	7	1480	484	6.61	9.18	6.94	10.1	6610	3.5
85-12-18	5.2 to 5.5	10-Jun-86		7.16	12	9290	12500	732	230	398	14	1720	523	6.31	10.4	6.91	12	8580	-2.3
		11-Sep-86		6.92	10	18300	15600	696	43	382	10	1800	575	5.92	11.5	8.33	14.4	7690	4.8
85-12-19	6 to 6.3	10-Jun-86		7.6	12	9260	12500	716	220	408	15	1550	747	6.99	9.95	6.73	13.4	8440	-2.4
		11-Sep-86		6.95	11	17800	14900	680	47	380	10	1590	708	5.64	10.5	7.78	15.4	7610	2.3
85-12-20	6.7 to 7	10-Jun-86		7.36	12	8890	12600	732	230	406	14	1630	538	6.95	10.3	6.73	14.3	8310	-2.5
		11-Sep-86		7.08	10	17400	15000	694	399	399	9	1670	585	6.29	10.5	7.67	16.4	7430	2.9
85-12-21	7.7 to 8	10-Jun-86		7.64	12	7460	12300	656	198	421	12	1170	516	7.58	9.26	5.45	17.4	6870	-5.3
		11-Sep-86		6.89	10	14200	11760	663	118	409	7	1210	521	6.54	9.85	6.11	18.5	5970	2.0

EXPLANATION OF COMMENTS - TABLE J1-1

- A - field duplicate sample
 B - field split sample
 C - laboratory duplicate
 D - results rejected because of high pH
 E - results rejected because of sediment in sample
 F - results rejected - tritium in sample indicates mixture with near surface water
 G - results rejected - ion balance > 10%
 H - results rejected - diluted by surface run off due to leakage through surface seal
 I - results rejected - probable dilution by drilling water
 J - these conductivities values were measured in the laboratory of Barringer Magenta Ltd

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TABLE J1-2

SUMMARY OF GROUND WATER CHEMISTRY DATA:
MINOR CATIONS AND ANIONS

Table J1-2 presents the results of laboratory analyses of ground water samples from the Preferred Site for minor ions. All concentrations are in mg/L except sulphide, which is in ug/L (ppb).

TABLE J1-2 : SUMMARY OF GROUND WATER CHEMISTRY DATA: MINOR CATIONS AND ANIONS

WELL IDENTIFICATION	SCREENED INTERVAL (depth in ft)	DATE SAMPLED	MINOR CATIONS														ANIONS									
			Ag	Al	B	Ba	Br	Ca	Co	Cu	Fe	Mn	Ni	P	Pb	Tb	Ti	V	Zn	Zr	Br	NO2	NO3	PO4	S	
			(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	
05-1-1	34.4 to 37.5	17-Jun-86 26-Aug-86	< .005	< .01	0.387	< .005	< .0045	(0.001)	< .05	0.04	< .008	0.42	0.03	< .2	0.05	< .5	< .05	< .005	< .005	0.21	< .05	< .5	< .2	< .5	< .5	
05-1-3	25.91 to 26.91	17-Jun-86 26-Aug-86	< .005	0.14	0.270	0.025	< .0045	< .01	< .05	0.02	0.024	0.22	< .01	< .2	< .05	< .5	< .05	< .005	< .005	0.02	< .05	< .5	< .2	0.8	< .5	
05-1-10	2.33 to 5.33	17-Jun-86 26-Aug-86	< .005	0.34	0.273	0.015	< .0045	< .01	< .05	< .01	< .008	2.77	0.19	< .2	0.07	0.9	< .05	< .05	0.014	< .005	0.1	< .05	< .5	< .2	< .5	
05-1-11	8.0 to 9.84	17-Jun-86 26-Aug-86	< .005	0.07	0.406	0.002	< .0045	< .01	< .05	0.06	0.011	1.4	0.17	< .2	0.07	0.6	< .05	< .05	0.01	< .005	0.53	< .05	< .5	< .2	< .5	
05-1-14	2.2 to 2.5	17-Jun-86 11-Sep-86	< .005	0.51	0.149	0.023	< .0045	< .01	< .05	3.05	0.014	0.04	0.02	< .2	0.05	0.6	< .05	< .05	0.01	0.012	0.55	< .05	< .5	< .2	2.2	
05-1-15	2.7 to 3	17-Jun-86 11-Sep-86	< .005	7.78	0.255	0.033	0.0046	(0.001)	< .05	0.15	0.051	1.4	0.34	< .2	0.07	1	< .05	< .05	0.15	0.033	0.67	< .05	< .5	< .2	4.8	
05-1-16	3.7 to 4	17-Jun-86 11-Sep-86	< .007	< .01	0.517	< .005	< .0045	< .01	< .05	0.08	< .008	0.06	< .01	< .2	< .05	0.6	< .05	< .05	< .005	0.008	0.72	< .05	< .5	< .2	3	
05-1-17	4.5 to 4.8	17-Jun-86 11-Sep-86	< .005	0.41	0.43	0.006	< .0045	< .01	< .05	0.03	0.016	0.92	0.08	< .2	0.08	0.8	< .05	< .05	< .005	0.01	< .05	< .05	< .5	< .2	< .5	
05-1-18	5.2 to 5.5	17-Jun-86 11-Sep-86	< .005	1.24	0.403	0.013	< .0045	< .01	< .05	0.02	0.028	2.51	0.17	< .2	0.1	0.9	< .05	< .05	0.025	0.006	< .05	< .05	< .5	< .2	< .5	
05-1-19	6 to 6.3	17-Jun-86 11-Sep-86	< .005	< .01	0.465	< .005	< .0045	< .01	< .05	0.07	< .008	0.2	0.12	< .2	0.07	0.8	< .05	< .05	< .005	< .005	< .05	< .05	< .5	< .2	4.3	
05-1-20	6.7 to 7	17-Jun-86 11-Sep-86	< .005	< .01	0.451	0.005	0.0006	< .01	< .05	0.04	0.014	0.27	0.26	< .2	0.09	0.9	< .05	< .05	< .005	< .005	< .05	< .05	< .5	< .2	< .5	
05-1-21	7.45 to 7.96	17-Jun-86 11-Sep-86	< .005	0.00	0.486	0.016	< .0005	< .01	< .05	0.02	0.016	0.52	0.27	< .2	0.12	0.9	< .05	< .05	< .005	0.012	< .05	< .05	< .5	< .2	< .5	

For explanation of comments see last page of this table

TABLE J1-2 : SUMMARY OF GROUND WATER CHEMISTRY DATA: MINOR CATIONS AND ANIONS

MONITOR #	SCREENED INTERVAL (depth in ft)	DATE SAMPLED	COMMENTS	MINOR CATIONS														MINOR ANIONS												
				Ag	Al	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	P	Pb	Th	Ti	V	Zn	Zr	Br	NO2	NO3	PO4	S		
				(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)			
85-2-4	15.5 to 16.6	12-Jun-86 26-Aug-86	E	<.005 0.011	<.01 <.01	0.399 0.342	0.026 0.019	<.0005 <.0005	0.002 <.0001	<.85 <.85	0.06 0.05	0.028 0.12	0.11 0.13	0.07 0.13	0.3 0.4	0.07 0.5	0.5 0.6	<.05 <.05	0.1 0.5	<.005 <.005	<.005 <.005	0.63 0.05	<.85 <.85	<.5 <.5	<.2 <.2	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5	
	32 to 34.69	12-Jun-86 26-Aug-86		<.005 0.008	<.01 <.01	0.468 0.443	0.006 <.0005	<.0005 <.0005	0.001 <.0001	<.85 <.85	0.05 0.06	0.008 0.17	0.02 0.02	0.02 0.02	<.2 <.2	0.07 0.5	<.5 <.5	<.05 <.05	0.05 0.05	<.005 <.005	<.005 <.005	0.11 0.05	<.85 <.85	0.5 <.5	<.2 <.2	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5	
85-3-10	2.3 to 5.3	12-Jun-86 26-Aug-86		<.005 <.005	0.24 <.01	0.462 0.462	<.005 <.005	<.0005 <.0005	0.01 <.01	<.85 <.85	<.01 0.00	0.008 0.12	0.19 <.01	<.01 <.01	<.2 <.2	0.1 0.09	0.9 1.1	<.05 <.05	<.05 <.05	<.005 <.005	<.005 <.005	0.05 0.05	<.85 <.85	<.5 <.5	<.2 <.2	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5	
	36.49 to 39.47	18-Jun-86 18-Jun-86	A	<.005 <.005	<.01 <.01	0.462 0.461	0.009 <.0005	<.0005 <.0005	0.001 <.0001	<.85 <.85	0.05 0.05	0.008 0.38	0.26 0.02	0.03 0.02	0.03 <.2	0.07 0.85	0.6 0.6	<.05 <.05	0.08 0.05	<.005 <.005	<.005 <.005	0.14 0.011	0.37 0.7	<.85 <.85	<.5 <.5	<.2 <.2	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5
85-8-4	15.16 to 16.16	18-Jun-86 21-Aug-86		<.005 <.005	<.01 <.01	0.34 0.364	0.013 0.013	<.0005 <.0005	0.002 <.0001	<.85 <.85	0.07 0.09	0.018 0.08	0.2 0.12	0.21 0.25	0.3 <.2	0.07 0.07	0.6 0.6	<.05 <.05	<.05 <.06	<.005 <.005	0.012 0.006	0.69 0.05	<.85 <.85	<.5 <.5	<.2 <.2	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5
	24.66 to 25.38	18-Jun-86 21-Aug-86		<.005 <.005	<.01 <.01	0.359 0.352	0.008 0.01	<.0005 <.0005	<.01 <.01	<.85 <.85	0.02 0.02	0.008 0.03	0.04 0.03	0.03 0.03	<.2 <.2	<.05 <.05	<.5 <.5	<.05 <.05	<.05 <.08	<.005 <.005	<.005 <.005	0.62 0.63	<.85 <.85	<.5 <.5	<.2 <.2	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5
85-8-8	2.43 to 5.33	18-Jun-86 21-Aug-86	A	<.005 <.005	0.11 <.01	0.359 0.283	0.012 <.005	<.0005 <.0005	0.001 <.0001	<.85 <.85	0.03 0.04	0.008 0.04	0.05 0.03	0.04 0.03	0.2 <.2	<.85 <.05	<.5 <.5	<.05 <.05	0.11 0.16	<.005 <.005	0.008 0.025	0.65 0.85	<.85 <.85	<.5 <.5	<.2 <.2	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5
	8.45 to 9.45	18-Jun-86 21-Aug-86	D	<.005 <.005	<.01 <.01	0.473 0.623	0.015 0.04	<.0005 <.0005	0.01 <.01	<.85 <.85	<.01 0.05	0.008 0.64	0.18 0.1	0.4 1.12	0.4 0.11	<.2 <.2	0.1 1	0.9 <.05	<.05 <.05	<.005 <.014	0.005 0.017	0.46 0.85	<.85 <.85	<.5 <.5	<.2 <.2	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5	<.5 <.5

For explanation of comments see last page of this table.

TABLE J1-2 : SUMMARY OF GROUND WATER CHEMISTRY DATA: MINOR CATIONS AND ANIONS

MONITOR #	SCREENED INTERVAL (depth in ft)	DATE SAMPLED	COMMENTS	MINOR CATIONS												MINOR ANIONS											
				Ag	Al	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Mn	Ni	P	Pb	Th	Ti	V	Zn	Zr	Br	NO2	NO3	PO4	S
				(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
05-10-1	34.85 to 39.85	12-Jan-86		< 0.05	0.05	0.325	0.01	< 0.005	0.001	< 0.05	0.06	0.21	0.04	< 2	0.07	0.5	< 0.05	< 0.05	0.005	0.009	< 0.05	< 0.05	0.7	< 2	< 5	< 10	7
		26-Aug-86		0.007	0.01	0.441	< 0.005	< 0.005	0.001	< 0.05	0.06	0.008	0.21	0.03	< 2	< 0.5	< 1.5	< 0.05	< 0.05	0.001	0.01	< 0.05	< 1.5	< 2	< 5	< 10	12
05-10-10	2.85 to 3.66	12-Jan-86	F	< 0.05	0.01	0.06	0.05	< 0.005	0.001	0.05	0.03	0.009	0.06	< 0.01	< 2	< 0.5	< 1.5	0.14	< 0.05	0.005	0.006	< 0.05	< 1.5	< 2	13.8	< 1	5
		26-Aug-86	F	0.009	0.71	0.09	0.049	< 0.005	< 0.01	0.05	0.04	0.008	0.03	0.02	< 2	< 0.5	< 1.5	< 0.05	< 0.05	0.034	< 0.05	< 0.05	< 1.5	< 2	14.2	< 10	12
05-11-4	16.78 to 17.7	12-Jan-86	C	< 0.05	0.41	0.321	0.031	< 0.005	< 0.01	< 0.05	0.03	0.008	0.44	0.03	< 2	< 0.5	< 1.5	< 0.05	0.006	0.005	< 0.05	0.4	< 2	< 5	< 10	4	
		26-Aug-86		0.007	0.01	0.305	0.014	< 0.005	0.001	0.05	0.04	0.008	0.06	0.05	0.3	< 0.5	< 1.5	< 0.05	0.08	0.001	0.012	< 0.05	< 1.5	< 2	< 7	< 10	12
05-12-1	38 to 41	10-Jan-86		< 0.05	0.05	0.464	0.005	< 0.005	0.001	< 0.05	0.04	0.008	0.2	0.03	< 2	0.06	0.6	< 0.05	< 0.05	0.005	0.01	< 0.05	< 1.5	< 2	< 5	< 10	15
		10-Jan-86	B	< 0.05	0.03	0.45	0.007	< 0.005	0.002	< 0.05	0.05	0.008	0.24	0.03	0.2	0.05	< 1.5	< 0.05	< 0.05	0.003	0.013	< 0.05	< 1.5	< 2	< 5	< 10	15
		21-Aug-86		< 0.05	0.01	0.421	0.006	< 0.005	0.001	0.05	0.06	0.008	0.2	0.02	< 2	< 0.5	< 1.5	< 0.05	< 0.05	0.003	< 0.05	< 0.05	< 1.5	< 2	< 5	< 10	12
		21-Aug-86	B	0.006	0.01	0.458	< 0.005	< 0.005	0.002	< 0.05	< 0.05	0.008	0.2	0.02	< 2	< 0.5	< 1.5	< 0.05	< 0.05	0.005	0.005	< 0.05	< 1.5	< 2	< 5	< 10	12
05-12-8	24.55 to 25.15	10-Jan-86		< 0.05	0.01	0.376	0.012	< 0.005	< 0.01	< 0.05	0.01	0.008	0.02	0.02	< 2	< 0.5	< 1.5	< 0.05	0.005	0.005	< 0.05	< 1.5	< 2	< 5	< 10	5	
		10-Jan-86	B	< 0.05	0.01	0.429	0.014	< 0.005	< 0.01	0.05	0.01	0.008	0.04	0.02	< 2	< 0.5	< 1.5	< 0.05	< 0.05	0.005	0.005	< 0.05	< 1.5	< 2	< 5	< 10	15
		21-Aug-86		< 0.05	0.11	0.375	0.013	< 0.005	< 0.01	0.05	0.01	0.008	0.02	0.02	< 2	< 0.5	< 1.5	< 0.05	0.08	0.003	0.006	< 0.05	< 1.5	< 2	< 7	< 10	12
		21-Aug-86	B	< 0.05	0.06	0.373	0.012	< 0.005	< 0.01	0.05	0.01	0.008	0.03	0.02	< 2	< 0.5	< 1.5	< 0.05	< 0.05	0.003	0.005	< 0.05	< 1.5	< 2	< 5	< 10	12
05-12-10	2.3 to 5.33	10-Jan-86		< 0.05	0.2	0.311	< 0.005	0.007	< 0.01	< 0.05	0.01	0.008	0.15	< 0.01	< 2	0.12	1	< 0.05	0.003	0.005	< 0.05	< 1.5	< 2	< 5	< 10	7	
		10-Jan-86	B	< 0.05	0.05	0.317	< 0.005	0.006	< 0.01	0.05	0.01	0.008	0.15	< 0.01	0.2	0.12	1.1	< 0.05	< 0.05	0.005	0.017	< 0.05	< 1.5	< 2	< 5	< 10	8
		21-Aug-86		< 0.05	0.01	0.343	< 0.005	< 0.005	< 0.01	0.05	0.07	0.008	0.18	< 0.01	0.2	0.1	1	< 0.05	< 0.05	0.014	0.005	< 0.05	< 1.5	< 2	1.2	< 10	12
		21-Aug-86	B	0.012	0.01	0.334	0.005	< 0.005	< 0.01	0.05	0.11	0.012	0.13	< 0.01	0.2	0.1	1	< 0.05	< 0.05	0.005	0.005	< 0.05	< 1.5	< 2	< 5	< 10	12
05-12-11	8.55 to 9.45	10-Jan-86		< 0.05	0.06	0.495	0.013	< 0.005	< 0.01	< 0.05	0.05	0.008	0.18	0.45	< 2	0.11	0.8	< 0.05	0.005	0.005	< 0.05	< 1.5	< 2	< 5	< 10	15	
		26-Aug-86		< 0.05	0.01	0.402	0.006	< 0.005	0.002	< 0.05	0.11	0.012	0.46	0.77	0.3	0.08	0.7	< 0.05	0.1	0.008	0.023	< 0.05	< 1.5	< 2	< 5	< 10	12
05-12-13	1.2 to 1.5	10-Jan-86		< 0.05	0.46	0.154	0.019	< 0.005	< 0.01	< 0.05	0.05	0.041	0.5	0.03	< 2	0.07	0.9	< 0.05	< 0.05	0.005	0.012	< 0.05	< 1.5	< 2	< 5	< 10	
05-12-14	2.2 to 2.5	10-Jan-86		< 0.05	0.08	0.233	< 0.005	0.007	< 0.01	0.08	0.01	0.017	0.17	< 0.01	0.3	0.11	1	< 0.05	< 0.05	0.003	0.014	< 0.05	< 1.5	< 2	< 5	< 10	15
		11-Sep-86		< 0.05	0.02	0.245	< 0.005	0.0035	< 0.01	0.05	0.07	0.013	0.32	0.04	< 2	0.09	1	< 0.05	< 0.05	0.005	0.005	< 0.05	< 1.5	< 2	1.2	< 10	12

For explanation of comments see last page of this table

TABLE J1-2 : SUMMARY OF GROUND WATER CHEMISTRY DATA: MINOR CATIONS AND ANIONS

MONITOR #	SCREENED INTERVAL (depth in ft)	DATE SAMPLED	COMMENT	MINOR CATIONS														MINOR ANIONS										
				Ag	Al	B	Ba	Be	Cd	Ca	Cr	Cu	Fe	Mn	Mo	Ni	P	Pb	Th	Ti	V	Zn	Zr	Br	NO2	NO3	PO4	S
				(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	(log/L)	
05-12-15	2.7 to 3	10-Jun-86		< 005	0.86	0.26	< 005	0.0000	< 01	< 05	< 01	0.012	0.15	< 01	0.3	0.1	1	< 05	< 05	< 005	0.009	< 05	< 05	< 5	< 2	< 5	< 10	4
	3	11-Sep-86		< 005	0.25	0.29	< 005	< 0005	< 01	< 05	< 05	0.013	0.3	< 01	< 2	0.09	0.9	< 05	< 05	< 005	0.005	< 05	< 05	< 5	< 2	< 5	< 10	02
05-12-16	3.7 to 4	10-Jun-86		< 005	< 01	0.313	< 005	< 0005	< 01	< 05	< 01	0.009	0.15	< 01	< 2	0.1	1	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	< 5	< 10	05
	4	11-Sep-86		< 005	< 01	0.33	< 005	< 0005	< 01	< 05	0.05	< 008	0.32	< 01	< 2	0.08	0.9	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	< 5	< 10	02
05-12-17	4.5 to 4.8	10-Jun-86		< 005	0.06	0.327	< 005	0.0005	< 01	< 05	< 01	0.012	0.13	< 01	< 2	0.1	0.9	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	< 5	< 10	5
	4.8	11-Sep-86		< 005	0.04	0.339	< 005	< 0005	< 01	< 05	0.07	< 008	0.28	< 01	< 2	0.07	0.8	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	4.5	< 10	02
05-12-18	5.2 to 5.5	10-Jun-86		< 005	< 01	0.494	< 005	0.0000	< 01	< 05	< 01	0.012	0.16	0.27	0.2	0.12	1	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	< 5	< 10	05
	5.5	11-Sep-86		< 005	< 01	0.612	< 005	< 0005	< 01	< 05	0.04	< 008	0.32	0.3	< 2	0.08	0.9	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	< 5	< 10	02
05-12-19	6.5 to 6.3	10-Jun-86		< 005	< 01	0.499	< 005	0.0006	< 01	< 05	< 01	0.018	0.15	0.1	0.2	0.11	0.9	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	< 5	< 10	05
	6.3	11-Sep-86		< 005	< 01	0.571	< 005	< 0005	< 01	< 05	< 05	< 008	0.3	0.1	< 2	0.07	0.8	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	3	< 10	02
05-12-20	6.7 to 7	10-Jun-86		< 005	< 01	0.521	< 005	0.0000	< 01	< 05	< 01	0.02	0.18	0.23	0.3	0.14	1.1	< 05	< 05	< 005	0.017	< 05	< 05	< 5	< 2	< 5	< 10	8
	7	11-Sep-86		< 005	0.22	0.647	< 005	< 0005	< 01	< 05	0.05	< 008	0.29	0.76	< 2	0.07	0.9	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	< 5	< 10	02
05-12-21	7.7 to 8	10-Jun-86		< 005	< 01	0.469	< 008	0.0006	< 01	< 05	0.01	0.018	0.13	0.32	< 2	0.09	0.9	< 05	< 05	< 005	0.009	< 05	< 05	< 5	< 2	< 5	< 10	8
	8	11-Sep-86		0.012	0.06	0.658	< 005	< 0005	< 01	< 05	0.08	< 008	0.3	0.37	< 2	0.07	0.9	< 05	< 05	< 005	< 005	< 05	< 05	< 5	< 2	< 5	< 10	02

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EXPLANATION OF COMMENTS - TABLE J1-2 :

- a - field duplicate sample
- b - field split sample
- c - results rejected because of high pH
- d - results rejected because of sediment in sample
- e - results rejected - uric acid in sample indicates moisture with near surface water
- f - results rejected - diluted by surface run off due to leakage through surface seal
- g - results rejected - ion balance > 10%

J-14

TABLE J1-3

SUMMARY OF GROUND WATER CHEMISTRY DATA:
ORGANIC COMPONENTS AND ISOTOPES

Table J1-3 presents the results of laboratory analyses on ground water samples from the Preferred Site for selected organic components and isotopes. The organic components were dissolved organic carbon (as mg/L) and methane (as parts per million by volume). The reader is referred to Appendix B3.1.2 for a discussion of the variability in the dissolved organic carbon results, and to Appendix B3.1.3 for a discussion of the variability in methane results. The isotopes analyzed were oxygen-18 (^{18}O), deuterium (^2H) and tritium (^3H). Oxygen-18 and deuterium results are expressed in the standard δ ‰ format with respect to SMOW. This is the difference (δ) in isotopic ratios ($^{18}\text{O}/^{16}\text{O}$) and ($^2\text{H}/^1\text{H}$) of the sample in parts per thousand (per mil or ‰) with respect to Standard Mean Ocean Water (SMOW). The tritium (^3H) results are expressed in Tritium Units (T.U.) where 1 T.U. equals 1 tritium atom in 10^{18} hydrogen atoms. The tritium results include analyses at three different levels of detection. Direct counting results have an analytical error of ± 6 to 8 T.U. Enriched counting results have an analytical error of ± 0.7 to 1.2 T.U. Results from enriched counting of low level activity have an analytical error of ± 0.1 T.U.

TABLE J1-3 : SUMMARY OF GROUND WATER CHEMISTRY DATA: ORGANIC COMPONENTS AND ISOTOPE5

MONITOR #	SCREENED INTERVAL (depth in m)	DATE SAMPLED	ORGANIC COMPONENTS		ISOTOPE5		
			Dissolved Organic Carbon E (ug/L)	Methane (ppm by volume)	Oxygen 18 (o/oo SMOW)	Deuterium (o/oo SMOW)	Tritium (T.U.)
85-1-1	34.4 to 37.5	17-Apr-86					(6 +/- 6
		17-Jun-86	16.5		-10.49	-78.7	
		20-Aug-86			-10.34 +/- 0.12 C	-73.4 +/- 0.4 C	
		20-Aug-86 B			-10.54 B	-73.9	
		26-Aug-86	16.5	56.3			1.3 +/- 0.7
		18-Sep-86		56.8			
85-1-3	25.91 to 26.91	14-Apr-86					96 +/- 8
		17-Jun-86	21		-12.83	-89.8	(6 +/- 8
		30-Jul-86					(6 +/- 8
		26-Aug-86	13	40.5 0			
		18-Sep-86		62.9			1.7 +/- 8
85-1-10	2.33 to 5.33	17-Apr-86					(6 +/- 8C
		17-Jun-86	99		-9.52	-70	(6 +/- 7
		26-Aug-86	18	5.8 0			
		18-Sep-86		10.5			
85-1-11	8.8 to 9.84	17-Jun-86	82		-10.36	-78.6	(6 +/- 8
		30-Jul-86					(6 +/- 8
		26-Aug-86	9.5	9.3 0			
		18-Sep-86		22			
85-1-14	2.2 to 2.5	17-Jun-86	14.5		-8.86	-61.4	35 +/- 7
		11-Sep-86	11				
		18-Sep-86		5.8			
85-1-15	2.7 to 3	17-Apr-86					(6 +/- 6
		17-Jun-86	32		-8.97	-61.2	(6 +/- 7
		11-Sep-86	10				10.0 +/- 1.0
		18-Sep-86		11.9			
85-1-16	3.7 to 4	17-Apr-86					(6 +/- 6
		17-Jun-86	54		-8.86	-63.3	(6 +/- 7
		11-Sep-86	9				1.5 +/- 0.7
		18-Sep-86		3			

For explanation of A, B, C etc. see last page of this table.

TABLE J1-3 : SUMMARY OF GROUND WATER CHEMISTRY DATA: ORGANIC COMPONENTS AND ISOTOPEs

MONITOR #	SCREENED INTERVAL (depth in m)	DATE SAMPLED	ORGANIC COMPONENTS		ISOTOPEs		
			Dissolved Organic Carbon E ($\mu\text{g/L}$)	Methane (ppm by volume)	Oxygen 18 (o/oo SMOW)	Deuterium (o/oo SMOW)	Tritium (T.U.)
85-1-17	4.5 to 4.8	17-Apr-86					6 ± 6
		17-Jun-86	55		-8.94	-64.9	6 ± 7
		11-Sep-86	10				2.4 ± 0.9
		18-Sep-86		4.7			
85-1-18	5.2 to 5.5	17-Apr-86					6 ± 6
		17-Jun-86	17		-9.06	-66.7	6 ± 8
		11-Sep-86	6				0.8 ± 0.7
		18-Sep-86		4.4			
85-1-19	6 to 6.3	17-Apr-86					6 ± 6
		17-Jun-86	8.5		-9.49	-68.4	6 ± 7
		11-Sep-86	6				$0.8 \pm 0.8C$
		18-Sep-86		4.8			
85-1-20	6.7 to 7	17-Apr-86					6 ± 6
		17-Jun-86	29		-9.55	$-67.9 \pm 0.3 C$	6 ± 7
		11-Sep-86	5				0.8 ± 0.8
		18-Sep-86		105			
85-1-21	7.65 to 7.96	17-Apr-86					6 ± 6
		17-Jun-86	27		-10.06	-72	6 ± 7
		11-Sep-86	3.5				0.8 ± 0.8
		18-Sep-86		7.9			
85-2-4	15.5 to 16.6	12-Jun-86	27		-10.65	-78.9	64 ± 8
		30-Jul-86					6 ± 8
		20-Aug-86			$11.0 \pm 0.04 C$		6 ± 8
		26-Aug-86	15.5	24.2 D			
		18-Sep-86		58.6			1.6 ± 0.6

For explanation of A, B, C etc. see last page of this table.

TABLE J1-3 : SUMMARY OF GROUND WATER CHEMISTRY DATA: ORGANIC COMPONENTS AND ISOTOPES

MONITOR #	SCREENED INTERVAL (depth in m)	DATE SAMPLED	ORGANIC COMPONENTS		ISOTOPES		
			Dissolved Organic Carbon E (mg/L)	Methane (ppm by volume)	Oxygen 18 (o/oo SMOW)	Deuterium (o/oo SMOW)	Tritium (T.U.)
85-3-1	32 to 34.69	15-Apr-86					6 +/- 6
		12-Jun-86	20		-10.17	-75.1 +/- 0.8 C	
		20-Aug-86			-10.65	-77.1 +/- 0.6 C	
		26-Aug-86	12.5	79.2 D			
		18-Sep-86		126.8			2.6 +/- 0.9
85-3-10	2.3 to 5.3	17-Apr-86					6 +/- 6
		12-Jun-86	39		-8.42	-64.4	8 +/- 7
		26-Aug-86		3.5 D			
		18-Sep-86		4.6			
85-8-1	36.49 to 39.47	15-Apr-86					6 +/- 7C
		18-Jun-86	55		-11.07 +/- 0.04 C	-80.40 C	
		18-Jun-86 A	36		-11.03 A	-79.7 A	
		20-Aug-86			-11.16	-79.4 +/- 0.0 C	
		26-Aug-86	30	105.6 D			
		26-Aug-86 A	42	118.3 A, D			
		18-Sep-86		100.6			0.8 +/- 0.7
		18-Sep-86 A		138.2 A			
85-8-3	25.83 to 26.83	17-Oct-86		105.6			
85-8-4	15.16 to 16.16	15-Apr-86					104 +/- 8
		18-Jun-86	78		-11.6	-82.5	6 +/- 7
		30-Jul-86					6 +/- 8
		21-Aug-86	31	44.3 D			
		18-Sep-86		82			3.1 +/- 0.8
85-8-8	24.66 to 25.38	18-Jun-86	23		-12.95	-91	19 +/- 7
		18-Jun-86 A	5.5		-12.92 A	-94.9 +/- 2.7 C	19 +/- 7
		14-Jul-86					6 +/- 7
		21-Aug-86	16	4.8 D			
		21-Aug-86 A	27	5 A, D			
		18-SEP-86		4.2			1 +/- 0.8
		18-SEP-86 A		4.4 A			0.8 +/- 0.8
85-8-10	2.43 to 5.33	15-Apr-86					6 +/- 7
		18-Jun-86	70		-9.04	-63.2 +/- 1.1 C	35 +/- 7
		18-Jun-86 A	23 A		-9.04 A	-61.8 A	
		21-Aug-86	31	2.5 D			
		21-Aug-86 A	35	2.4 A, D			
		18-Sep-86		6.2			
		18-Sep-86 A		6.3 A			
85-8-11	8.45 to 9.45	18-Jun-86	21		-10.06	-71.9	8 +/- 8 C
		30-Jul-86					9 +/- 8 C
		21-Aug-86	26	9.8 D			
		18-Sep-86		20.6			

For explanation of A, B, C etc. see last page of this table

TABLE J1-3 : SUMMARY OF GROUND WATER CHEMISTRY DATA: ORGANIC COMPONENTS AND ISOTOPIES

MONITOR #	SCREENED INTERVAL (depth in m)	DATE SAMPLED	ORGANIC COMPONENTS		ISOTOPIES		
			Dissolved Organic Carbon E (mg/L)	Methane (ppm by volume)	Oxygen 18 (o/oo SMOW)	Deuterium (o/oo SMOW)	Tritium (T.U.)
85-10-1	36.85 to 39.85	15-Apr-86					(6 +/- 7
		12-Jun-86	4		-11.28	-82.9	
		20-Aug-86			-11.4	-82.6	
		26-Aug-86	7	37.6 D			
		18-Sep-86		68.5			(0.8 +/- 0.8
85-10-10	2.85 to 3.66	15-Apr-86					45.5 +/- 9 C
		12-Jun-86	35		-8.74	-62.5	
		26-Aug-86	40	5.3 D			
		18-Sep-86		6.3			
85-11-4	16.78 to 17.7	12-Jun-86	48	34.3	-13.31	-95.2	(6 +/- 8
		30-Jul-86					10 +/- 8
		26-Aug-86	17.5				
		18-Sep-86		125 +/- 0.7 C			(0.8 +/- 0.7
85-12-1	38 to 41	15-Apr-86					(6 +/- 7
		10-Jun-86	16	247.6	-11.2	-82.1	
		10-Jun-86 B	18.5 B	289.4 B	-11.06 B	-82.4 B	
		20-Aug-86			-11.38	-80.7	
		21-Aug-86	10	127.7 D			
		21-Aug-86 B	21	131.2 B, D			
		18-Sep-86		539.6			(0.8 +/- 0.8
		18-Sep-86 B		466.9 B			
85-12-3	25.9 to 26.8	17-Oct-86		258			
85-12-8	24.55 to 25.15	10-Jun-86	30	290.8	-13.21	-96.9	(6 +/- 7
		10-Jun-86 B	17 B	311.1 B	-13.4	-92.7	(6 +/- 7
		14-Jul-86					(6 +/- 7
		14-Jul-86 B					
		21-Aug-86	21	2.2 D			
		21-Aug-86 B	21	4.2 B, D			
		18-Sep-86		10.7			(0.8 +/- 0.7
		18-Sep-86 B		7 B			(0.8 +/- 0.8
85-12-10	2.3 to 5.33	15-Apr-86					14 +/- 7
		10-Jun-86	29	2.5	-9.13 +/- 0.16 C	-63	
		10-Jun-86 B	30 B	2.5 B	-9.01 B	-63.5 B	
		21-Aug-86	49	2.9 D			
		21-Aug-86	30	3.2 B, D			
		18-Sep-86		4.6			
		18-Sep-86 B		4.6 B			

For explanation of A, B, C etc. see last page of this table.

TABLE J1-3 SUMMARY OF GROUND WATER CHEMISTRY DATA: ORGANIC COMPONENTS AND ISOTOPES

MONITOR #	SCREENED INTERVAL (depth in m)	DATE SAMPLED	ORGANIC COMPONENTS		ISOTOPES		
			Dissolved Organic Carbon E (mg/L)	Methane (ppm by volume)	Oxygen 18 (o/oo SMOW)	Deuterium (o/oo SMOW)	Tritium (T.U.)
85-12-11	8.55 to	10-Jun-86	45	18.6	-10.63	-78.7	6 +/- 8
		30-Jul-86					6 +/- 8
	9.45	26-Aug-86	20				
		18-Sep-86		23.4			
85-12-13	1.2 to	15-Apr-86					42 +/- 7
	1.5	10-Jun-86	50	1.1	-8.26	-61.8	
85-12-14	2.2 to	15-Apr-86					56 +/- 7
	2.5	10-Jun-86	45	3.4	-8.92	-62.7 +/- 1.1 C	
		11-Sep-86	8				
		18-Sep-86		2.1			
85-12-15	2.7 to	15-Apr-86					25 +/- 7
	3	15-Apr-86 B					39 +/- 7
		10-Jun-86	48	3.7	-9.05	-61.4	
		11-Sep-86	9				
85-12-16	3.7 to	15-Apr-86					23 +/- 7
		10-Jun-86	43	3.4	-9.31 +/- 0.05 C	-63.8	
		11-Sep-86	10				
		18-Sep-86		2.7			
85-12-17	4.5 to	15-Apr-86					20 +/- 7
	4.8	10-Jun-86	50	5.2	-9.51	-68.8	
		11-Sep-86	10				
		18-Sep-86		10.9			
85-12-18	5.2 to	15-Apr-86					6 +/- 7
	5.5	10-Jun-86	43	6.5	-9.84	-73.2	
		02-Jul-86					0.25 +/- 0.10
		11-Sep-86	10.5				
		18-Sep-86		8			

For explanation of A, B, C etc. see last page of this table.

TABLE J1-3 : SUMMARY OF GROUND WATER CHEMISTRY DATA: ORGANIC COMPONENTS AND ISOTOPES

MONITOR #	SCREENED INTERVAL (depth in m)	DATE SAMPLED	ORGANIC COMPONENTS		ISOTOPES		
			Dissolved Organic Carbon E (mg/L)	Methane (ppm by volume)	Oxygen 18 (o/oo SNOW)	Deuterium (o/oo SNOW)	Tritium (T.U.)
85-12-19	6 to 6.3	15-Apr-86					6 +/- 7
		10-Jun-86	40	7.7	-10	-71.7	0.14 +/- 0.10
		02-Jul-86					
		11-Sep-86	10				
		18-Sep-86		6.2			
85-12-20	6.7 to 7	15-Apr-86					6 +/- 8 A
		10-Jun-86	26	4.6	-10.33	-75.5	-0.05 +/- 0.10
		02-Jul-86					
		11-Sep-86	15				
		18-Sep-86		7.5			
85-12-21	7.7 to 8	15-Apr-86					11 +/- 7
		15-Apr-86 B					6 +/- 7
		10-Jun-86	19	14.5	-10.94	-77.9	0.11 +/- 0.10
		02-Jul-86					
		11-Sep-86	4				
		18-Sep-86		12			

Explanatory footnotes for Table J1-3 :

A - FIELD DUPLICATE SAMPLE

B - FIELD SPLIT SAMPLE

C - AVERAGE OF TWO LABORATORY DUPLICATES

D - RESULT SUSPECT BECAUSE OF INCORRECT EQUILIBRATION PERIOD AT LABORATORY

E - ANALYSIS METHODOLOGY SUSCEPTIBLE TO CONSIDERABLE VARIABILITY

J-22

TABLE J1-4

ORGANIC "PRIORITY POLLUTANT" SCAN - MONITOR 85-12-1

JULY 2, 1986

Table J1-4 presents laboratory analysis results for a partial organic "priority pollutant" scan on one ground water sample taken from monitor 85-12-1 on July 2, 1986. The list of organic "priority pollutants" was determined by the United States Environmental Protection Agency and represents compounds which are common ground water, drinking water or surface water contaminants as well as common or toxic by-products of industrial and agricultural processes. The analysis presented in Table J1-4 did not include pesticide, PCB, dioxin or dibenzofuran "priority pollutants". All analyses are provided in ug/L (ppb). A laboratory blank water sample was also analyzed to provide a check on the analytical methods.

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TABLE J1-4:

PRIORITY POLLUTANT SCAN - MONITOR 85-12-1 - JULY 2, 1986

VOLATILE ORGANICS

Conc. = ppb

VOLATILE COMPOUNDS	MDL (ppb)	LAB WATER BLANK	85-12-1			
DICHLORODIFLUOROMETHANE	2.0	--	--	--	--	--
CHLOROMETHANE	2.0	--	--	--	--	--
VINYL CHLORIDE	2.0	--	--	--	--	--
BROMOMETHANE	2.0	--	--	--	--	--
CHLOROETHANE	2.0	--	--	--	--	--
TRICHLOROFLUOROMETHANE	2.0	--	--	--	--	--
1,1-DICHLOROETHYLENE	1.0	--	--	--	--	--
DICHLOROMETHANE	1.0	--	--	--	--	--
T-1,2-DICHLOROETHYLENE	1.0	--	--	--	--	--
1,1-DICHLOROETHANE	1.0	--	--	--	--	--
CHLOROFORM	1.0	TR	--	--	--	--
1,2-DICHLOROETHANE	1.0	--	--	--	--	--
1,1,1-TRICHLOROETHANE	1.0	--	--	--	--	--
BENZENE	0.5	TR	1.9	--	--	--
CARBON TETRACHLORIDE	1.0	--	--	--	--	--
1,2-DICHLOROPROPANE	1.0	--	--	--	--	--
BROMODICHLOROMETHANE	1.0	--	--	--	--	--
TRICHLOROETHYLENE	1.0	--	--	--	--	--
1,3-DICHLOROPROPENE (Z)	1.0	--	--	--	--	--
1,3-DICHLOROPROPENE (E)	1.0	--	--	--	--	--
1,1,2-TRICHLOROETHANE	1.0	--	--	--	--	--
TOLUENE	0.5	TR	--	--	--	--
DIBROMOCHLOROMETHANE	1.0	--	--	--	--	--
TETRACHLOROETHYLENE	1.0	--	--	--	--	--
CHLOROBENZENE	0.5	--	--	--	--	--
ETHYL BENZENE	0.5	--	--	--	--	--
P & M XYLENE	0.5	TR	--	--	--	--
BROMOFORM	1.0	--	--	--	--	--
O-XYLENE	0.5	--	--	--	--	--
1,1,2,2-TETRACHLOROETHANE	1.0	--	--	--	--	--
1,3-DICHLOROBENZENE	1.0	--	--	--	--	--
1,4-DICHLOROBENZENE	1.0	--	--	--	--	--
1,2-DICHLOROBENZENE	1.0	--	--	--	--	--
1,2,4-TRICHLOROBENZENE	1.0	--	--	--	--	--

TR = TRACE AMOUNT DETECTED

-- = NONE DETECTED

MDL = METHOD DETECTION LIMIT

4813-EX

BASE/NEUTRAL EXTRACTABLES

Conc. = ppb

TABLE J1-4: PRIORITY POLLUTANT SCAN - MONITOR 85-12-1 - JULY 2, 1986

BASE NEUTRAL COMPOUNDS	MDL	TRAV				
	(ppb)	BLANK	85-12-1			
BIS(2-CHLORO ETHYL)ETHER	1.0	--	--	--	--	--
1,4-DICHLOROBENZENE	1.0	--	--	--	--	--
1,3-DICHLOROBENZENE	1.0	--	--	--	--	--
BIS(2-CHLOROISOPROPYL)ETHER	1.0	--	--	--	--	--
1,2-DICHLOROBENZENE	1.0	--	--	--	--	--
NITROBENZENE	1.0	--	--	--	--	--
N-NITROSO-DI-N-PROPYL-AMINE	3.0	--	--	--	--	--
HEXACHLOROETHANE	1.0	--	--	--	--	--
ISOPHORONE	1.0	--	--	--	--	--
BIS(2-CHLORO ETHOXY)METHANE	2.0	--	--	--	--	--
NAPHTHALENE	1.0	--	--	--	--	--
1,2,4-TRICHLOROBENZENE	1.0	--	--	--	--	--
HEXACHLOROBUTADIENE	1.0	--	--	--	--	--
HEXACHLOROCYCLOPENTADIENE	1.0	--	--	--	--	--
2-CHLORONAPHTHALENE	1.0	--	--	--	--	--
2,6-DINITROTOLUENE	2.0	--	--	--	--	--
DIMETHYL PHTHALATE	2.0	--	--	--	--	--
ACENAPHTHYLENE	1.0	--	--	--	--	--
ACENAPTHENE	1.0	--	--	--	--	--
2,4-DINITROTOLUENE	2.0	--	--	--	--	--
DIETHYL PHTHALATE	2.0	--	--	--	--	--
9H FLUORENE	1.0	--	--	--	--	--
4-CHLOROPHENYL PHENYL ETHER	1.0	--	--	--	--	--
N-NITROSO DIPHENYLAMINE	4.0	--	--	--	--	--
1,2-DIPHENYL HYDRAZINE	5.0	--	--	--	--	--
4-BROMOPHENYL PHENYL ETHER	1.0	--	--	--	--	--
HEXACHLOROBENZENE	1.0	--	--	--	--	--
PHENANTHRENE	1.0	--	--	--	--	--
ANTHRACENE	1.0	--	--	--	--	--
DI-N-BUTYL PHTHALATE	1.0	--	--	--	--	--
FLUORANTHENE	1.0	--	--	--	--	--
BENZIDENE	5.0	--	--	--	--	--
PYRENE	2.0	--	--	--	--	--
BUTYL BENZYL PHTHALATE	2.0	--	--	--	--	--
CHRYSENE	2.0	--	--	--	--	--
BENZO(A)ANTHRACENE	2.0	--	--	--	--	--
3,3-DICHLOROBENZIDENE	5.0	--	--	--	--	--
BIS(2-ETHYL HEXYL)PHTHALATE	2.0	--	--	--	--	--
DI-N-OCTYL PHTHALATE	2.0	22.0	13.1	--	--	--
BENZO(A)PYRENE	2.0	--	--	--	--	--
BENZO(K)FLUORANTHENE	2.0	--	--	--	--	--
BENZO(B)FLUORANTHENE	2.0	--	--	--	--	--
DIBENZO(AH)ANTHRACENE	2.0	--	--	--	--	--
BENZO(GHI)PERYLENE	2.0	--	--	--	--	--
INDENO(123-CD)PYRENE	2.0	--	--	--	--	--

TR = TRACE AMOUNT DETECTED

-- = NONE DETECTED

MDL = METHOD DETECTION LIMIT

4813-ACID
TABLE J1-4

PRIORITY POLLUTANT SCAN - MONITOR 85-12-1 - JULY 2, 1986

ACID EXTRACTABLES

Conc. = ppb

ACID COMPOUNDS	MDL (ppb)	TRAV BLANK	85-12-1			
PHENOL	3.0	--	--	--	--	--
2-CHLOROPHENOL	2.0	--	--	--	--	--
2,4-DIMETHYL PHENOL	2.0	--	--	--	--	--
P-CHLORO-M-CRESOL	5.0	--	--	--	--	--
2,4-DICHLOROPHENOL	2.0	--	--	--	--	--
2,4,6-TRICHLOROPHENOL	2.0	--	--	--	--	--
2-NITROPHENOL	5.0	--	--	--	--	--
4-NITROPHENOL	5.0	--	--	--	--	--
2,4-DINITROPHENOL	3.0	--	--	--	--	--
4,6-DINITRO-O-CRESOL	5.0	--	--	--	--	--
PENTACHLOROPHENOL	2.0	--	--	--	--	--

TR = Trace Amount Detected

-- = None Detected

MDL = Method Detection Limit

J-27

TABLE J1-5

OXYGEN-18, DEUTERIUM AND CHLORIDE RESULTS
FROM PORE WATER SQUEEZING

Table J1-5 present laboratory analysis results for chloride (in mg/L) and the isotopes oxygen-18 and deuterium (in δ ‰ SMOW) on ground waters (or pore waters) "squeezed" from soil samples. See the write-up of Table J1-3 for an explanation of δ ‰ SMOW. Shelby tube soil samples taken from various depths in the overburden at locations 85-1-22 and 85-12-12 were used for pore water squeezing. Pore water squeezing techniques are described in Appendix B1.5.

TABLE J1-5 : OXYGEN-18, DEUTERIUM AND CHLORIDE RESULTS FROM PORE WATER SQUEEZING

SHELBY TUBE NO	DEPTH RANGE (a)	MIDPOINT DEPTH (a)	$\delta^{18}\text{O}$ (o/oo snow)	$\delta^2\text{H}$ (o/oo snow)	Cl (mg/L)
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LOCATION 85-1 (soil samples collected from borehole 85-1-22)

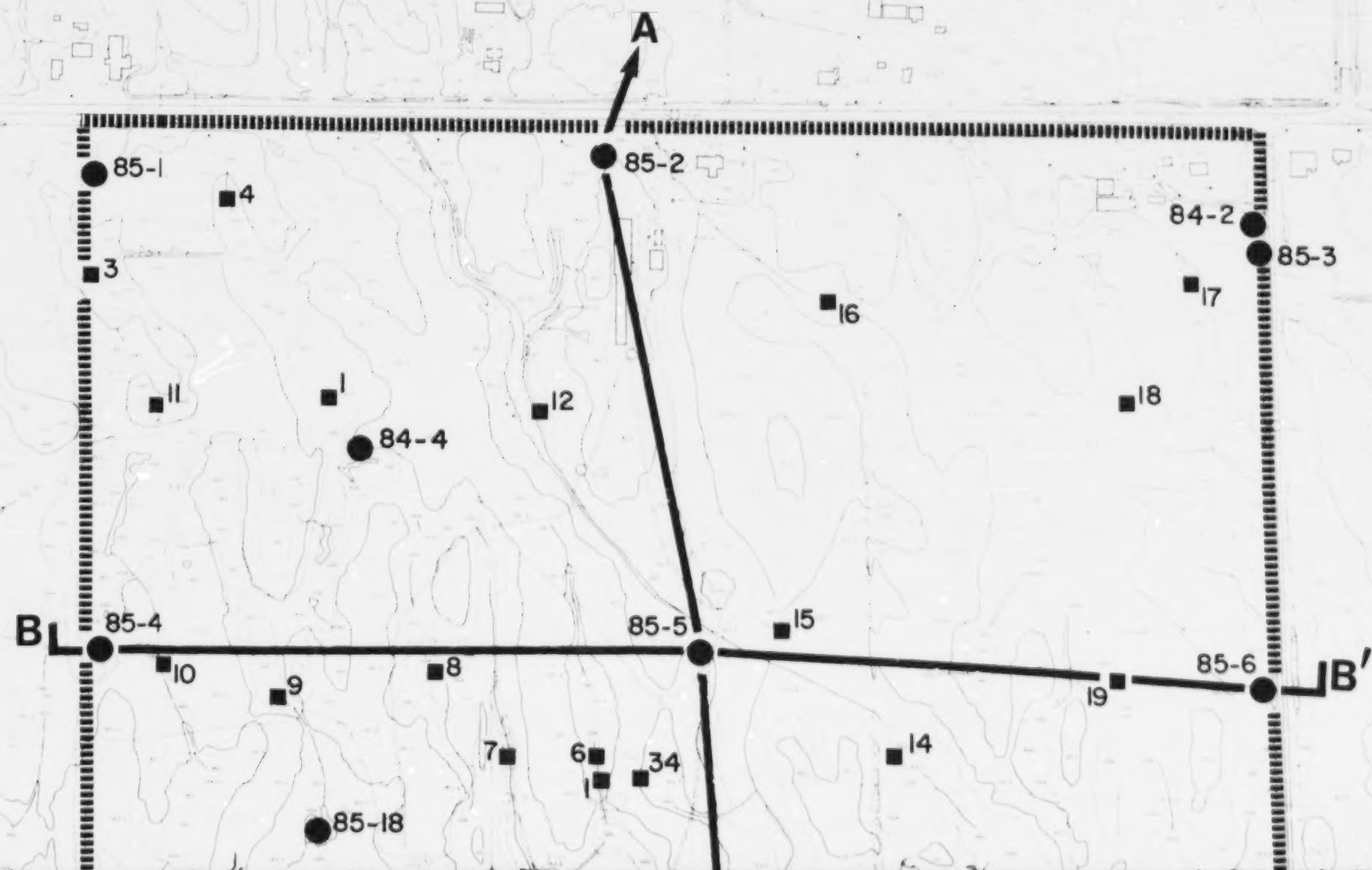
1	1.32 to 2.13	1.83	-8.33	-60.9	8.7
2	3.05 to 3.46	3.36	-8.83	-63.5	42.2
3	4.57 to 5.10	4.88	-9.04	-65.6	29.4
4	6.1 to 6.71	6.41	-9.30	-70.2	30.4
5	9.14 to 9.76	9.45	-10.00	-75.3	28.2
7	12.19 to 12.8	12.50	-10.64	-79.0	28.7
9	15.85 to 16.46	16.16	-11.53 +/- 0.22 B	-80.4	25.2
	15.85 to 16.46	16.16	-11.41 A	-79.6 A	26.0 A
10	18.29 to 18.9	18.60	-12.01	-88.5	26.6
11	21.33 to 21.95	21.64	-12.28 +/- 0.06 B	-89.4	33.0
13	24.38 to 24.99	24.69	-13.07	-92.0	30.1
14	27.43 to 28.04	27.74	-13.02	-92.3	34.8
16	30.48 to 31.09	30.79	-13.09	-92.7	31.1
	30.48 to 31.09	30.79	-13.07 A	-93.4 A	29.4 A

LOCATION 85-12 (soil samples collected from borehole 85-12-12)

1	1.32 to 2.13	1.83	-9.12 +/- 0.22 B	-61.1	28.1
2	3.05 to 3.65	3.35	-9.63	-63.6	81.1
3	4.57 to 5.18	4.88	-9.90	-68.8	27.5
4	6.1 to 6.71	6.41	-10.07	-70.2	29.5
5	9.14 to 9.75	9.45	-11.17	-76.9	18.6
	9.14 to 9.75	9.45	-11.06 A	-78.7 A	18.5 A
6	12.19 to 12.8	12.50	-11.7 +/- 0.06 B	-78.5	18.2
7	15.24 to 15.85	15.55	-12.22	-82.8	17.8
8	18.29 to 18.9	18.60	-12.72	-86.1	19.0
9	21.34 to 21.95	21.65	-13.13	-91.4	21.1
	21.34 to 21.95	21.65	-13.17 A	-93.7 A	20.9 A
10	24.38 to 24.99	24.69	-13.60	-95.6	23.5
11	27.43 to 28.04	27.74	-13.82	-95.9	23.6
12	30.48 to 31.09	30.78	-13.92	-99.4	23.8
13	33.53 to 34.14	33.84	-13.99	-100.9	22.5

A - Pore water from duplicate squeezing of soil sample
 B - Laboratory duplicate analysis

Highway No. 20





Consultant



Legend

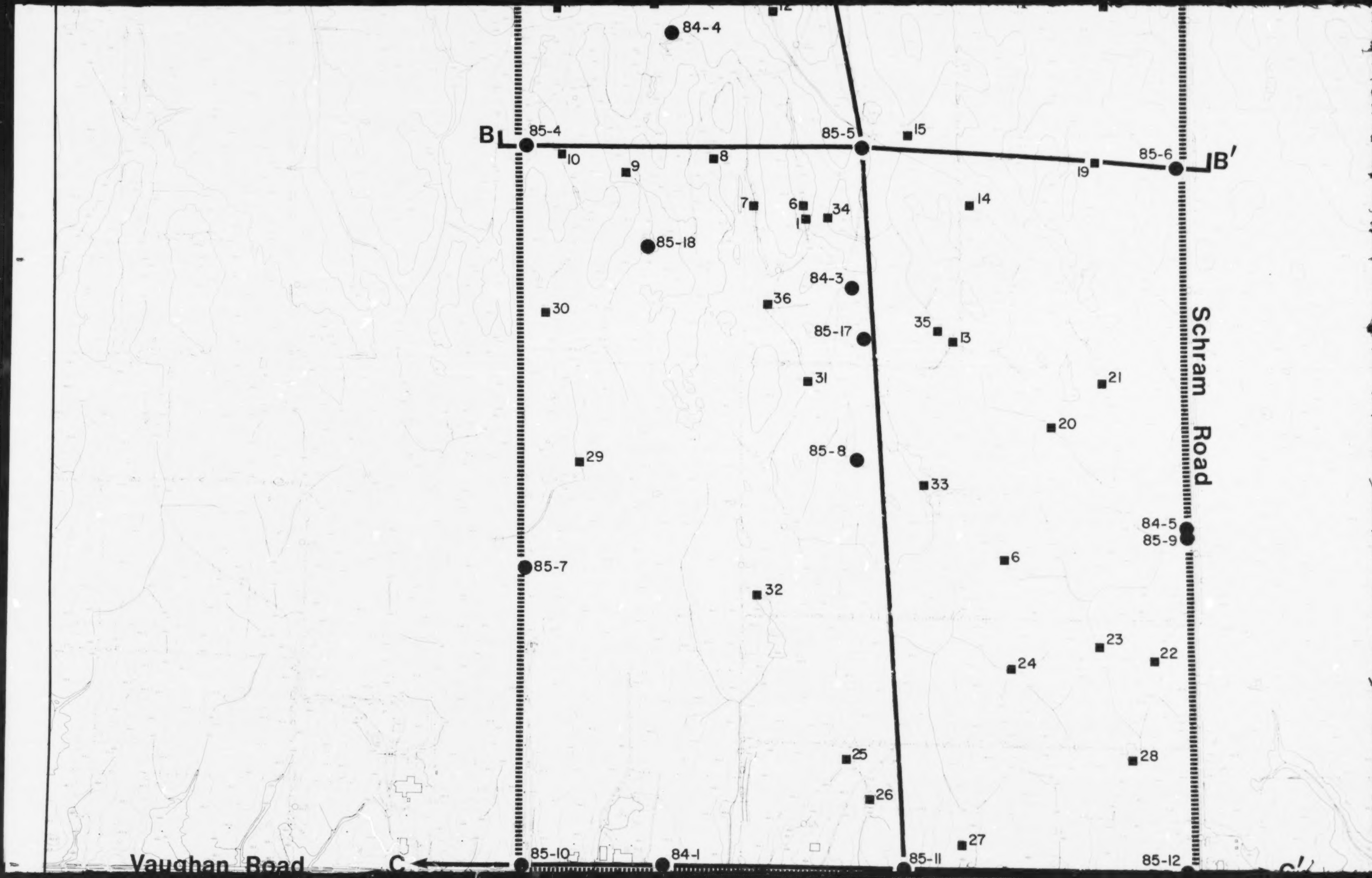
● 84-2 Borehole location, year and number

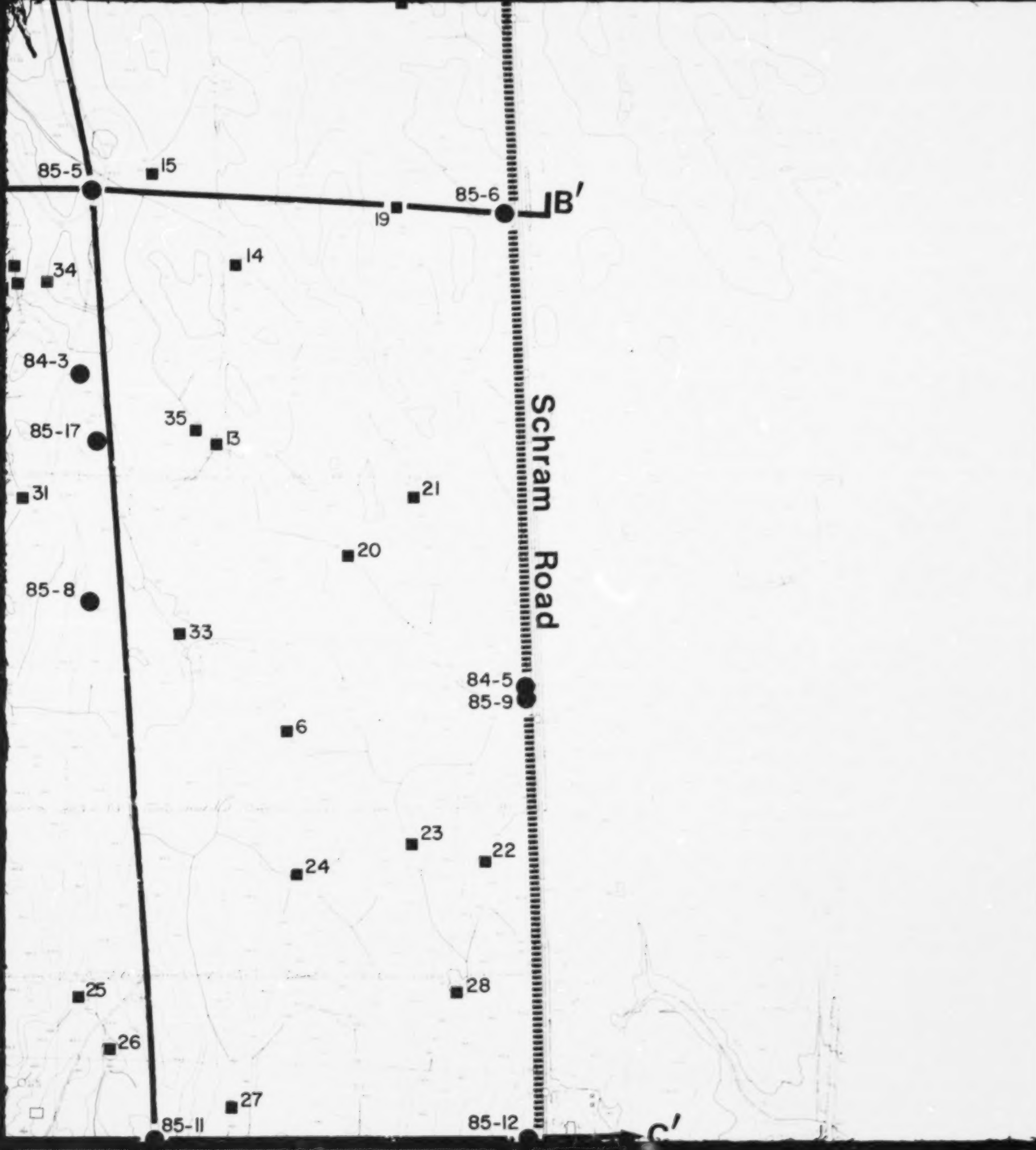
■ 24 Field station location and number

BL **JB'** Cross section location

----- Site boundary

NOTE: Cross-sections A-A' and C-C' include off-site boreholes 85-13, 85-14, 85-15 and 85-16 and are indicated **C** $\longleftrightarrow$ **C'**. These boreholes are noted on Figure 1-3

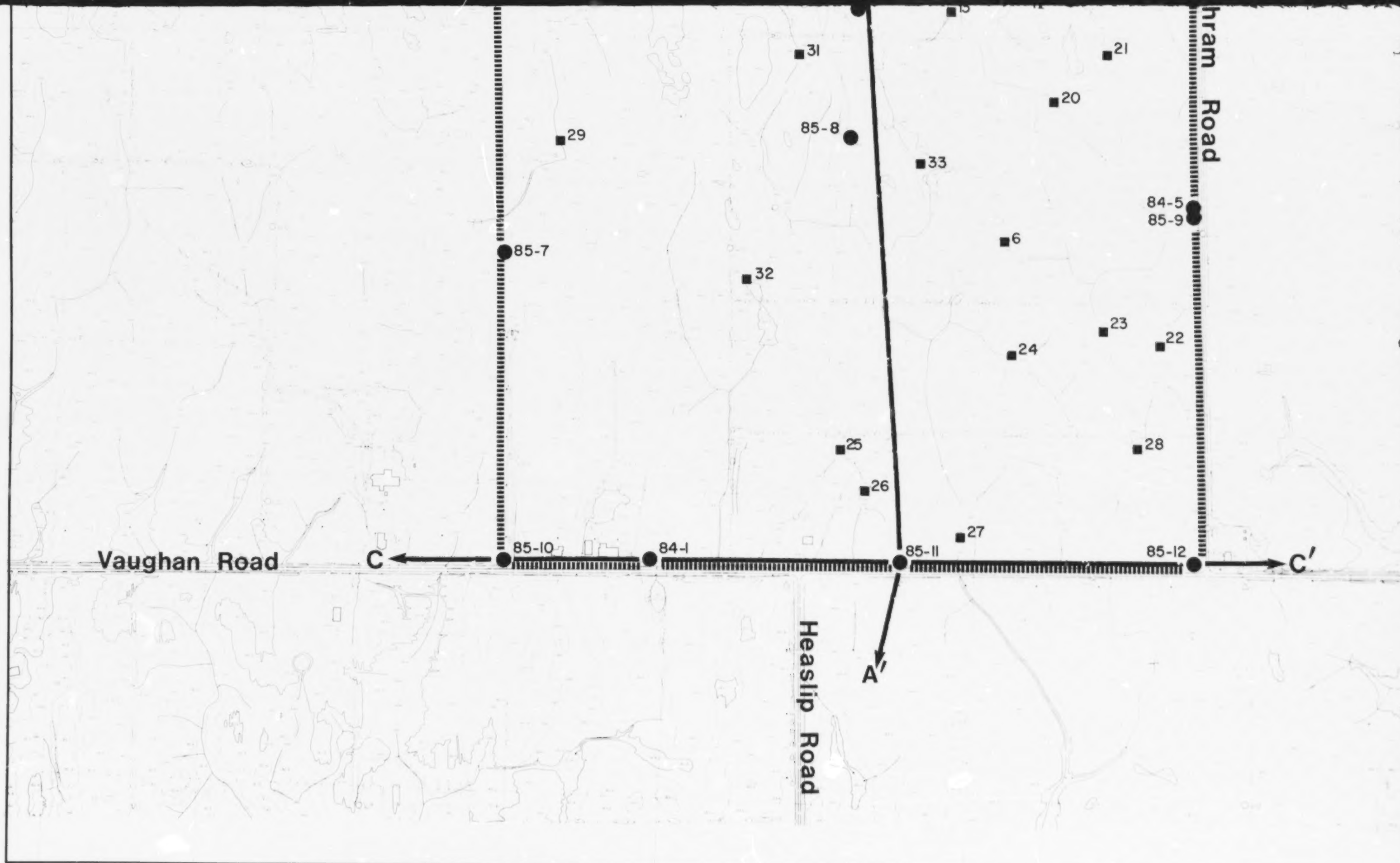


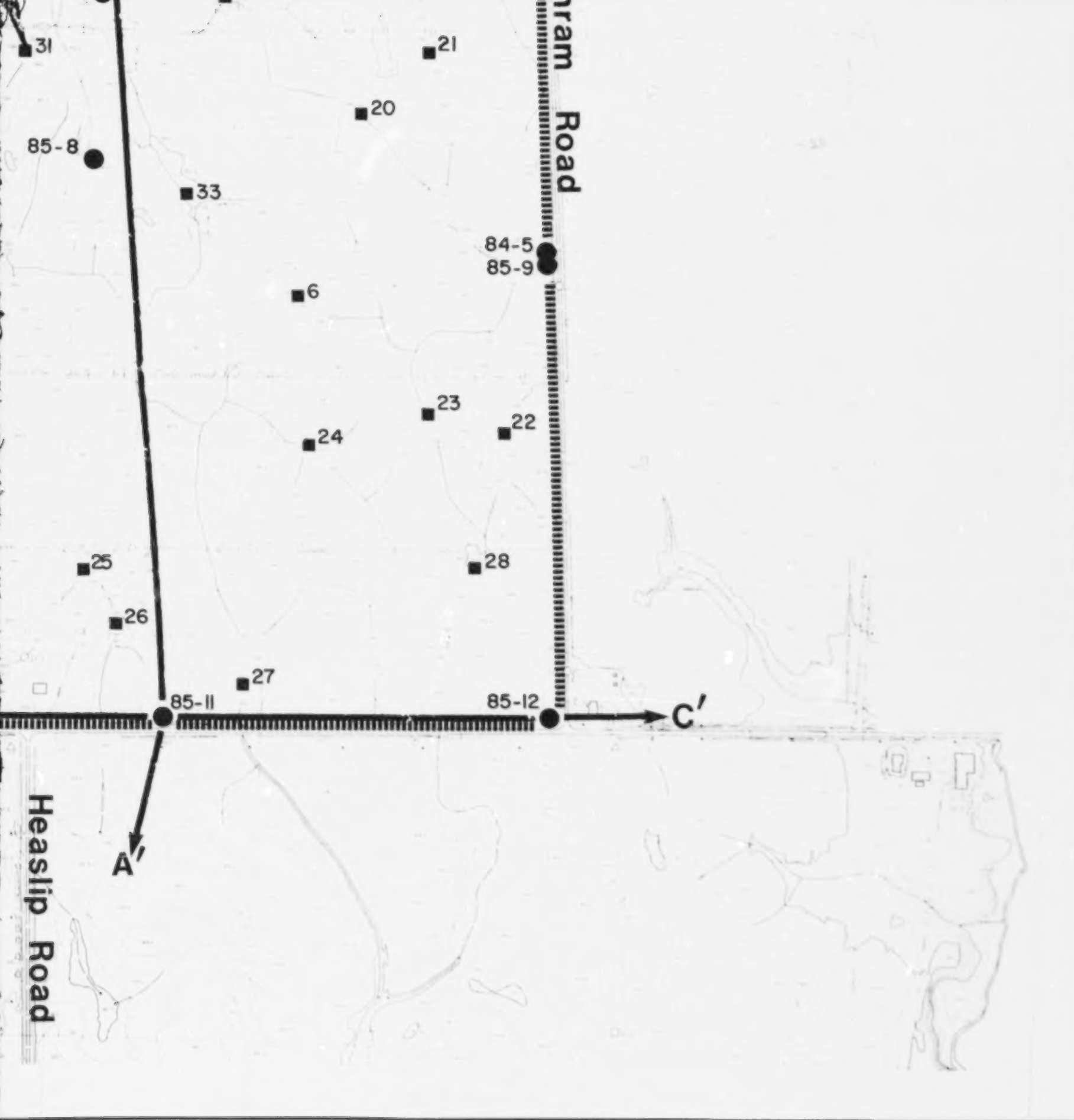


----- Site boundary

NOTE: Cross-sections A-A' and C-C' include off-site boreholes 85-13, 85-14, 85-15 and 85-16 and are indicated **C** $\longleftrightarrow$ **C'**. These boreholes are noted on Figure 1-3

100 0 100 200 300 Metres





100 0 100 200 300 Metres

BOREHOLE & FIELD STATION LOCATIONS (on-site)

Figure 2-1

